E83-10242
TM-85275

GL.04

LANDSAT-D Investigations Workshop

May 13-14, 1982

Goddard Space Flight Center

Day 2

(E83-10242) LANDSAT-D INVESTIGATIONS WORKSHOP (NASA) 265 p HC A12/MF A01 CSCL 05A

N83-21483

Unclas
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Agenda

LANDSAT-D INVESTIGATIONS WORKSHOP

Friday, 14 May 1982

8:00 am	Informal Investigations Team Interaction	
8:30 am	Introduction to TM Characterization	Barker
	TM Radiometric Sensor Performance • Spectral Information • Absolute Calibration • Ground Processing	
10:15 am	BREAK	
10:30 am	TM Geometric Sensor Performance	Engel
11:30 am	TM Geometric Processing — Flight Segment	Beyer
12:30 pm	Lunch and Informal Investigations Team Interaction	

Friday, 14 May 1982 (Cont.)

1:45 pm	TM Geometric Processing — Ground Segment	Beyer
3:00 pm	Early Access TM Processing	Fischel
3:45 pm	Wrap-Up Panel Discussion	Science Team
4:15 pm	Informal Investigations Team Interaction	

Introduction to TM Characterization

John Barker

Landsat-D Science Office
TM Characterization Objectives

- Characterize Accuracy and Precision of Imagery
- Characterize Accuracy and Precision of Derived Information
- Recommend Landsat-D System Improvements
- Communicate Capabilities to Research Community

Areas of Investigation

- Sensor and Spacecraft Performance
- Image Data Quality
- Applications Information

Support

- Applications Notice (AN) Investigations
- GSFC Support
  - Studies Discipline
  - Procedure and Performance Assessment (PAPA)
- Landsat-D Project
  - SBRC
  - GE
  - CSC
  - ORI

GSFC Support

- TM Investigations Discipline Support
  - Studies Planned to Complement AN Investigations
  - Scientific Representatives Support Individual ANs
- Product and Procedure Assessment (PAPA)
  - Collection of Interactive Image Analysis Software
  - Accepts Wide Variety of Image Formant Inputs (ADT, CCT, IPF, VICAR, etc.)
  - Primarily for In-House Assessment of TM Products and Processing Techniques

Sensor and Spacecraft Performance Characterization
Radiometry of TM

			Anuta	Bender	Slater	Wrigley	Erickson	Hovis	Schott	MacDonald				
Spectral Resolution	Spectral Matching	Filter												
		Detectors												
		System		●	●					●				
Radiometric Resolution	Absolute Integrating Sphere Calibration					●								
	External Calibration		●	●	●	●	●	●	●	●				
	Internal Calibration	Precision												
		Signal-to-Noise	●	●			●			●				
	Flooding Lamp Calibration													

Sensor and Spacecraft Performance Characterization

Geometry of TM

Geometry of Image (Pixel Location)			Colewell	Bernstein	Anuta	Bender	Wrigley	Erickson	Keiffer	Guerney	Everett			
	Sensor Effects	Scan Profile, Reference Detector		●	●	●	●		●	●				
		Detector Location Relative to Reference Detector	●	●	●	●	●	●	●		●			
		Between Scan Alignment		●	●									
	Ephemeris	Orbital Support Competing Div.												
		Global Positioning System (GPS)												
	Attitude	Angular Displacement Sensor (ADS)												
		Inertial Reference System (DRIRU)												
		Attitude Control System (ACS)												
		Alignment to Sensor												

Sensor and Spacecraft Performance Characterization
Geometry of TM (con't)

		Colewell	Bernstein	Anuta	Wrigley	Zobrist	Erickson	Welch					
Geometry of Pixel	Rise Time & Delay Time	●	●										
	Bright Target Recovery Time	●	●										
	MTF (IFOV) or Frequency Response Time	●	●	●	●		●	●					
	Bowtie Scan Angle Effect		●	●									
	Altitude Effects		●	●		●							

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Image Data Quality Performance Characterization
Radiometry of TM

			Colewell	Bernstein	Anuta	Bender	Slater	Erickson	Hovis	Schott	Everett	MacDonald		
Spectral Information	Detector Replacement Algorithms				●									
	Band Compression Algorithms													
Radiometric Information	Internal Calibration Algorithms	Channel-to-Channei			●				●			●		
		Band-to-Band			●				●					
	Scene Histogram Calibration Algorithms (Radiometric Destriping)			●	●				●	●	●	●		
	Absolute Scene Radiance Calibration Algorithms	Reflective Band	●			●	●		●		●			
		Thermal Band	●				●			●				
	Noise Correction Algorithms				●			●						

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Image Data Quality Performance Characterization
Geometry of TM

			Bernstein	Anuta	Bender	Wrigley	Zobrist	Erickson	Keiffer	Guerney	Everett	MacDonald		
Geometry of Pixel	Ground IFOV		●			●								
Geometry of Image (Pixel Location)	Systematic Correction	Scan Profile	●	●					●	●	●			
		Detector Location	●		●	●			●	●	●			
		Between Scan Alignment												
		Ephemeris					●				●			
		Attitude		●		●			●	●				
	Geodetic Correction with GCPs	Reference Library Build	●		●		●		●	●				
		Scene-to-Scene Registration			●	●	●	●	●					
	Resampling													

Applications Information — MSS & TM

		Name	Colewell	Bernstein	Anuta	Malila	Bender	Price	Slater	Wrigley	Malila	Zobrist	Erickson	Hovis	Lauer	Schott	Keiffer	Welch	Pozior	Guerney	Hill	Everett	MacDonald	Anderson						
		GSFC No.	AN 3	AN 8	AN 9	AN 12	AN 14	AN 15	AN 18	AN 20	AN 23	AN 25	AN 26	AN 29	AN 31	AN 32	AN 35	AN 36	AN 37	AN 39	AN 41	AN 42	AN 44	AN 46						
Renewable Resources	Agriculture																													
	Soils																													
	Forests																													
	Range																													
	Other																													
Non-Renewable Resources	Geology																													
	Image Science																													
	Other																													
Planning/ Environmental Management	Regional/Urban Land Use																													
	Coastal Zone																													
	Hydrology																													
	Wildlife Habitat																													
	Oceans																													
	Other																													

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TM Radiometric Sensor Performance

- Spectral Information
- Absolute Calibration
- Ground Processing

John Barker

OVERVIEW OF PRESENTATION

- SPECTRAL INFORMATION
- ABSOLUTE CALIBRATION
  - — DETECTORS
  - — INTERNAL CALIBRATOR
- NOISE CHARACTERIZATION
- POST CALIBRATION SENSOR HISTORY
- VERIFICATION OF CALIBRATION SYSTEM
- POST-LAUNCH TM RADIOMETRIC PRE-PROCESSING PROCEDURES

TM/PF RADIOMETRY

SPECTRAL INFORMATION

- SPECIFICATIONS
- RESULTS
- CALCULATED SPECTRAL RESPONSE CURVES
- COMPARISON OF TM TO MSS
- CONCLUSIONS

TM/PF SPECTRAL PERFORMANCE SPECIFICATIONS

BAND LOCATIONS AND RANGE

BAND	BAND EDGES AT HALF MAXIMUM		CALCULATED BANDWIDTH AT HALF MAXIMUM
	LOWER	UPPER	
	λ_{LS} (NM)	λ_{US} (NM)	$\Delta\lambda_S$ (NM)
1	450 ± 10	520 ± 10	70 ± 20 *
2	520 ± 10	600 ± 10	80 ± 20 *
3	630 ± 20	690 ± 10	60 ± 30 *
4	760 ± 20	900 ± 10	140 ± 30 *
5	1550 ± 20	1750 ± 20	200 ± 40 *
7	2080 ± 30	2350 ± 30	270 ± 60 *
6 (μM)	10.4 ± .1	12.5 ± .1	2.1 ± .2 *

*BANDWIDTH WAS NOT IN SPECIFICATION

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TM/PF SPECTRAL PERFORMANCE

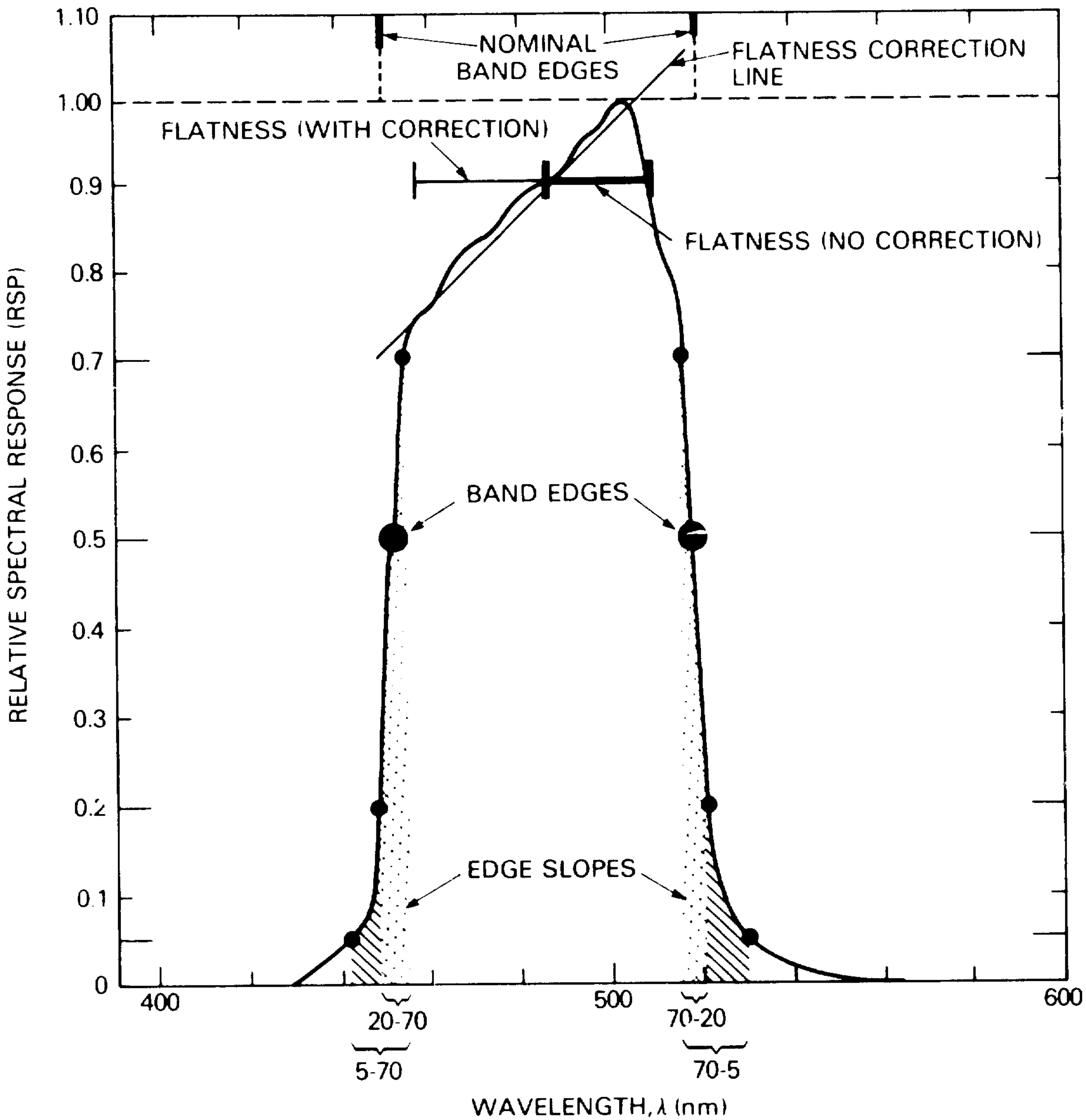
OBSERVED BAND LOCATIONS AND DIFFERENCES FROM SPECIFICATION

BAND	LOWER BAND EDGE AT HALF MAXIMUM		UPPER BAND EDGE AT HALF MAXIMUM		BANDWIDTH AT HALF MAXIMUM	
	OBSERVED λL (NM)	DIFFERENCE $\lambda L - \lambda LS$ (NM)	OBSERVED λU (NM)	DIFFERENCE $\lambda U - \lambda US$ (NM)	OBSERVED $\Delta\lambda$ (NM)	DIFFERENCE $\Delta\lambda - \Delta\lambda S$ (NM)
1	452	2	518	-2	66	-4
2	529	9	610	10	81	1
3	624	-6	693	3	69	9
4	776	16	905	5	129	-11
5	1568	18	$\boxed{1784}$	$\boxed{34\ *}$	216	16
7	2097	17	2347	-3	250	-20
6 (μM)	10.422	.022	$\boxed{11.661}$	$\boxed{-.839\ *}$	1.239	-.861

*OUT OF SPECIFICATION CHARACTERISTICS

TM/PF SPECTRAL PERFORMANCE SPECIFICATIONS
BAND SHAPES FOR BAND 1, 2, 3 AND 4

BAND	MAXIMUM EDGE INTERVAL (SLOPE)				MINIMUM FLATNESS
	LOWER EDGE RISE		UPPER EDGE FALLOFF		
	FROM 20% TO 70% OF PEAK (NM)	FROM 5% TO 70% OF PEAK (NM)	FROM 70% TO 20% OF PEAK (NM)	FROM 70% TO 5% OF PEAK (NM)	% OF BAND PASS WITHIN 10% OF PEAK (%)
1	20	30	20	40	75
2	20	30	20	40	75
3	20	30	20	40	75
4	20	30	30	40	75


NOMINAL BAND EDGES
FLATNESS CORRECTION LINE
FLATNESS (WITH CORRECTION)
FLATNESS (NO CORRECTION)
BAND EDGES
EDGE SLOPES
RELATIVE SPECTRAL RESPONSE (RSP)
1.10
1.00
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
500
600
20-70
5-70
70-20
70-5
WAVELENGTH, λ (nm)

TM/PF SPECTRAL PERFORMANCE

OBSERVED BAND SHAPES FOR BAND 1, 2, 3 AND 4

BAND	MAXIMUM EDGE INTERVAL (SLOPE) LOWER EDGE RISE FROM 20 % TO 70% OF PEAK (NM)	LOWER EDGE RISE FROM 5% TO 70% OF PEAK (NM)	UPPER EDGE FALLOFF FROM 70% TO 20% OF PEAK (NM)	UPPER EDGE FALLOFF FROM 70% TO 5% OF PEAK (NM)	MINIMUM FLATNESS % OF BAND PASS WITHIN 10% OF PEAK UNCORRECTED (%)	CORRECTED (%)
1	7	14	5	14	32	78
2	20	25	9	19	26	$\boxed{71}$ *
3	14	21	7	18	65	$\boxed{71}$ *
4	13	23	9	17	76	-

* OUT OF SPECIFICATION CHARACTERISTICS

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TM/PF SPECTRAL PERFORMANCE

BAND SHAPES FOR BANDS 5, 6 AND 7

BAND	MAXIMUM EDGE INTERVAL (SLOPE)				MINIMUM FLATNESS	
	LOWER EDGE RISE FROM 5% TO 75%		UPPER EDGE FALLOFF FROM 75% TO 5%		% OF BAND PASS WITHIN 10% OF PEAK (20% FOR TM6)	
	SPEC.	OBSERVED	SPEC.	OBSERVED	SPEC.	OBSERVED
5	50NM	32NM	50NM	42NM	75%	84%
7	80NM	75NM	80NM	37NM	75%	67% *
6	.30μM	.25μM	.30μM	1.01μM *	75%	59% *

* OUT OF SPECIFICATION CHARACTERISTICS

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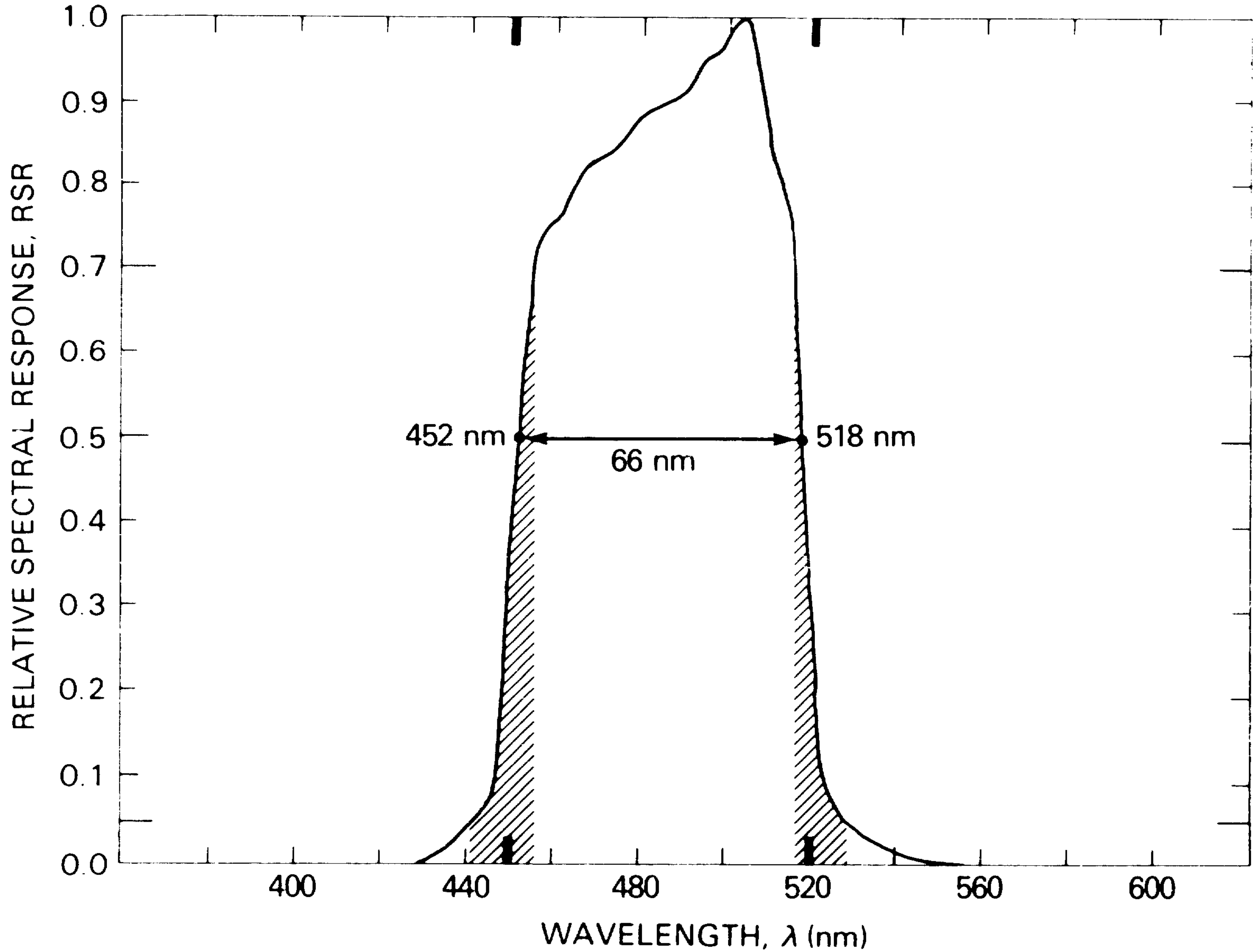
TM/PF BAND 6 SPECTRAL PERFORMANCE

DETECTOR/ TEMPERATURE	BAND EDGES (μM) 50% RESPONSE POINTS LOWER	UPPER	EDGE SLOPES (μM) LOWER 5% - 75%	UPPER 75% - 5%	FLATNESS % OF PASSBAND WITHIN 20% OF MAX
1 / 95°K	10.422	$\boxed{11.600}$ *	0.252	$\boxed{1.058}$ *	$\boxed{67.6}$ *
2 / 95°K	10.419	$\boxed{11.639}$ *	0.247	$\boxed{1.054}$ *	$\boxed{66.1}$ *
3 / 95°K	10.421	$\boxed{11.664}$ *	0.250	$\boxed{0.997}$ *	$\boxed{68.7}$ *
4 / 95°K	10.424	$\boxed{11.740}$ *	0.257	$\boxed{0.923}$ *	$\boxed{66.4}$ *
4 / 90°K	10.424	$\boxed{11.945}$ *	0.257	$\boxed{0.709}$ *	78.6
4 / 105°K **	10.411	$\boxed{11.327}$ *	0.240	$\boxed{1.225}$ *	$\boxed{70.3}$ *

*OUT OF SPECIFICATION CHARACTERISTICS ARE BOXED

**PREDICTION BASED ON ESTABLISHED BEHAVIOR OF HG CD TE

TM-PROTOFLIGHT BAND 1



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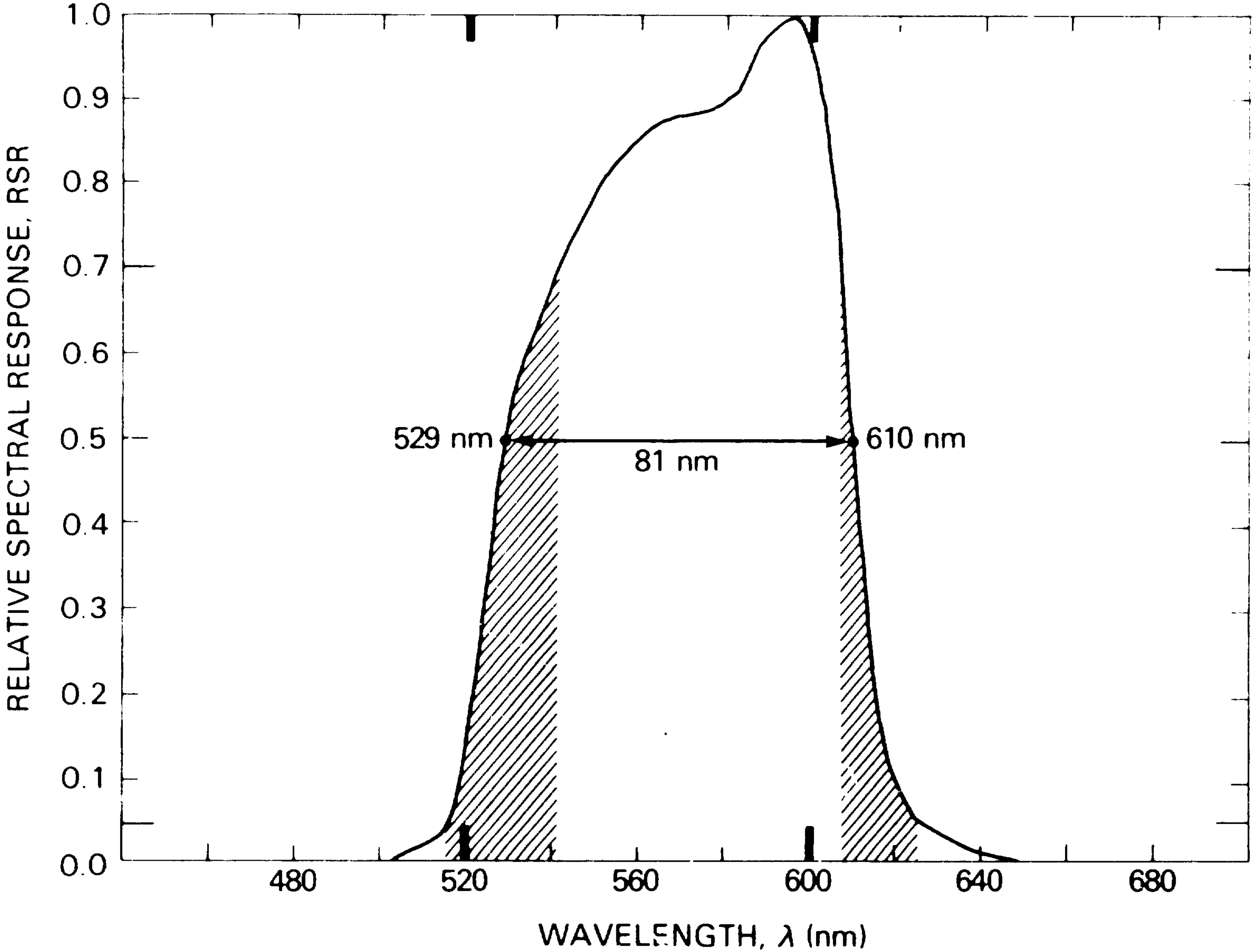
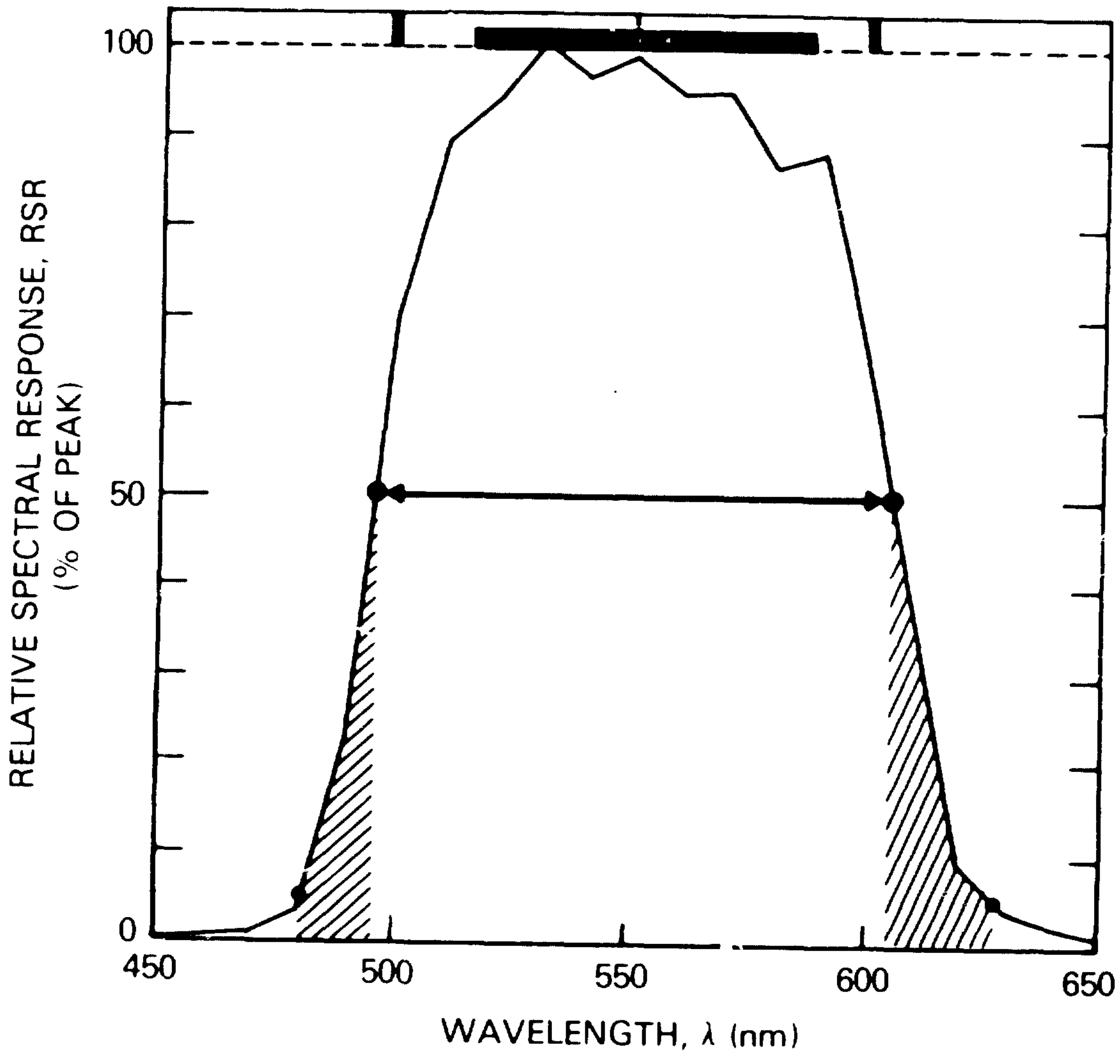
TM-PROTOFLIGHT BAND 2

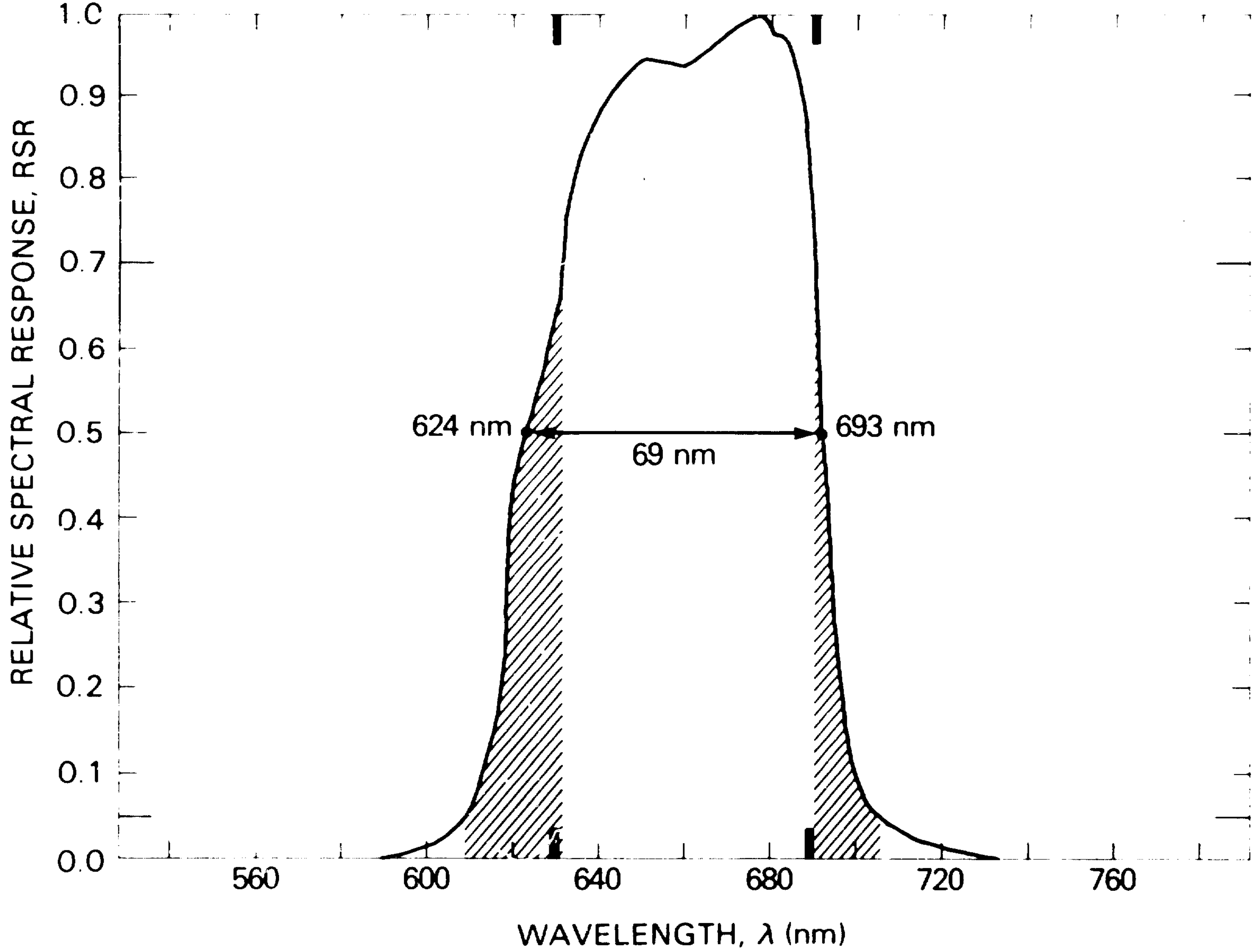


LANDSAT-4 MSS/PF SPECTRAL RESPONSE

BAND 1/CHANNEL 3
(SBRC - JUNE 18, 1981)

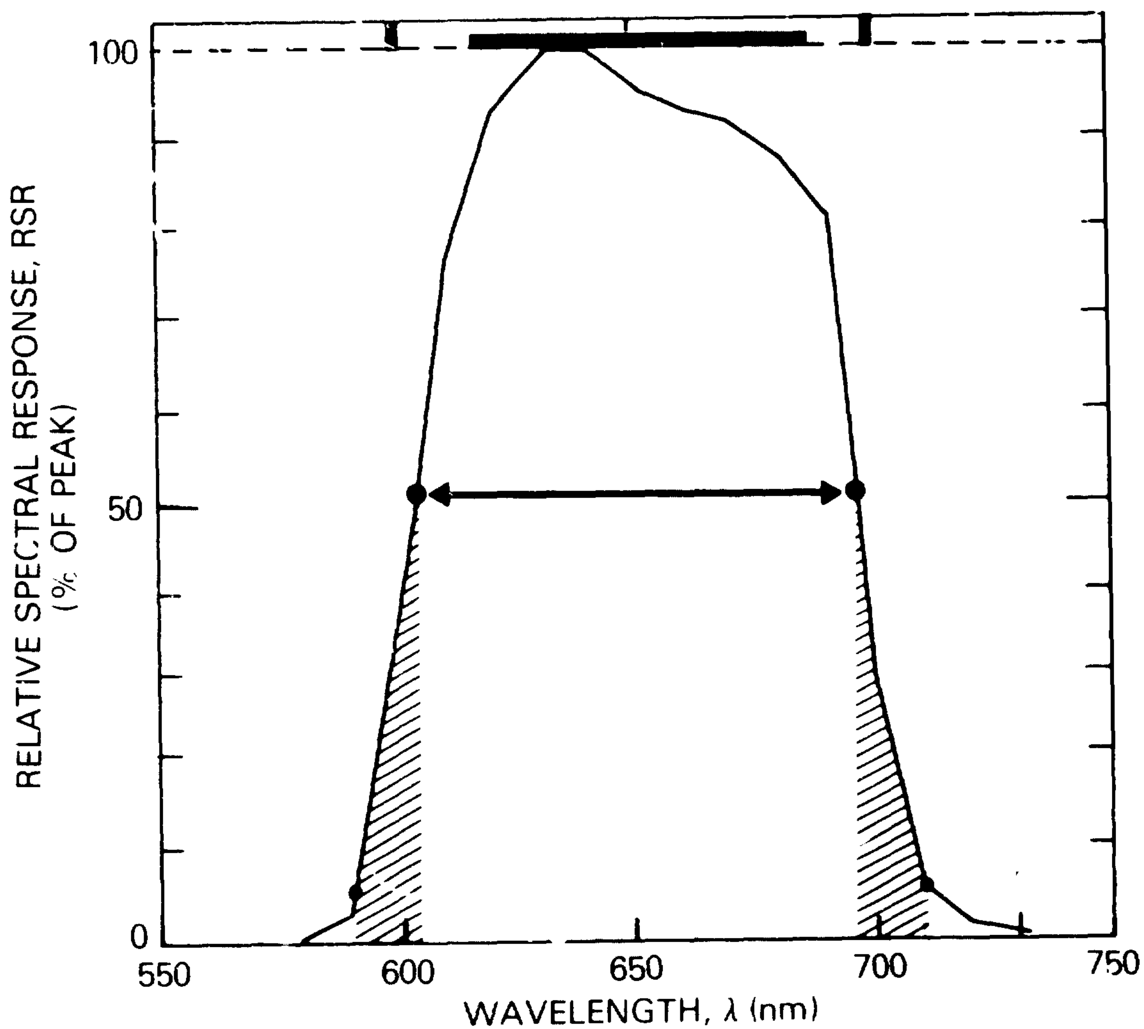


TM-PROTOFLIGHT BAND 3



LANDSAT-4 MSS/PF SPECTRAL RESPONSE

BAND 2/CHANNEL 9
(SBRC - JUNE 18, 1981)



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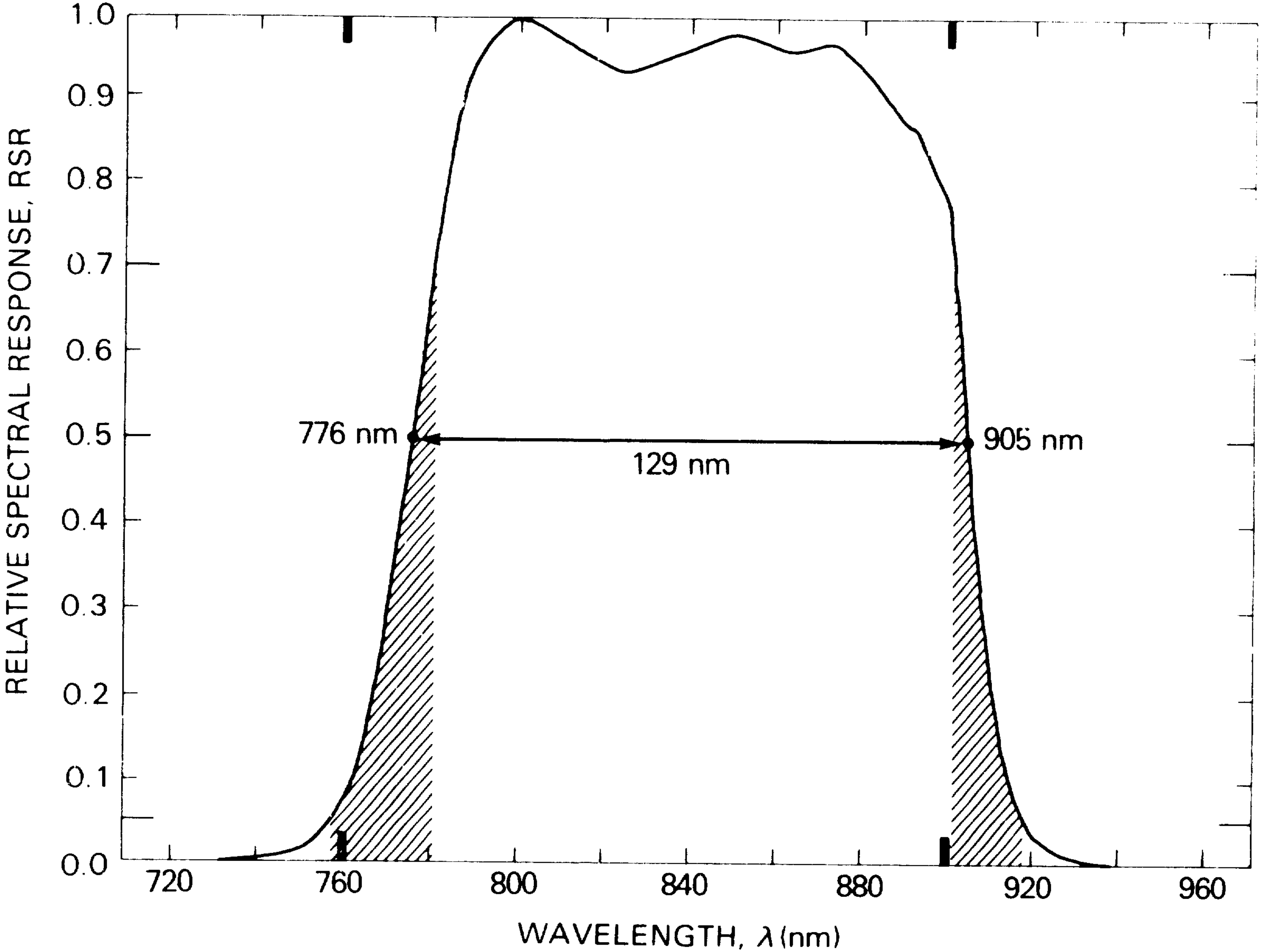
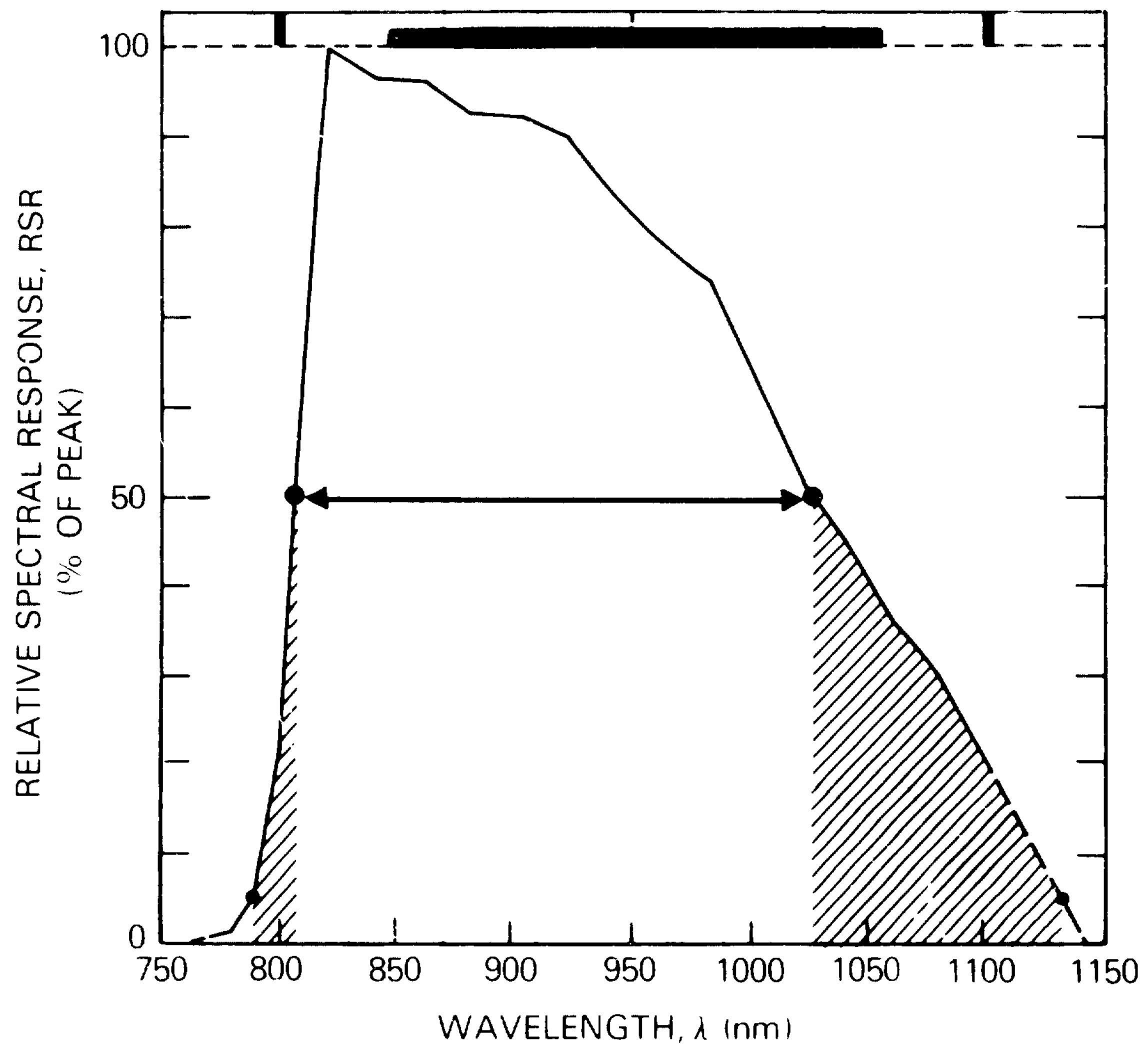
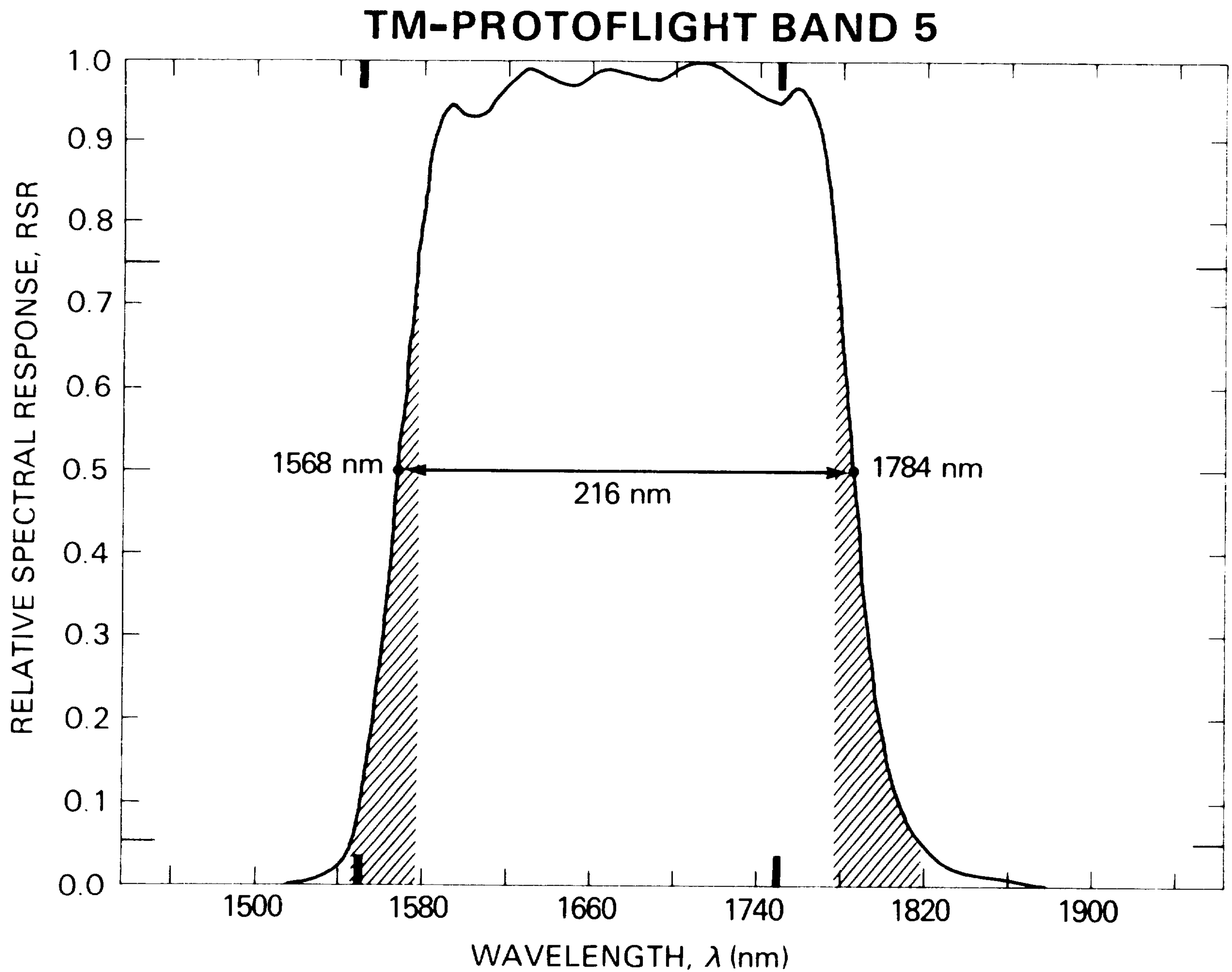
TM - PROTOFLIGHT BAND 4



LANDSAT-4 MSS/PF SPECTRAL RESPONSE

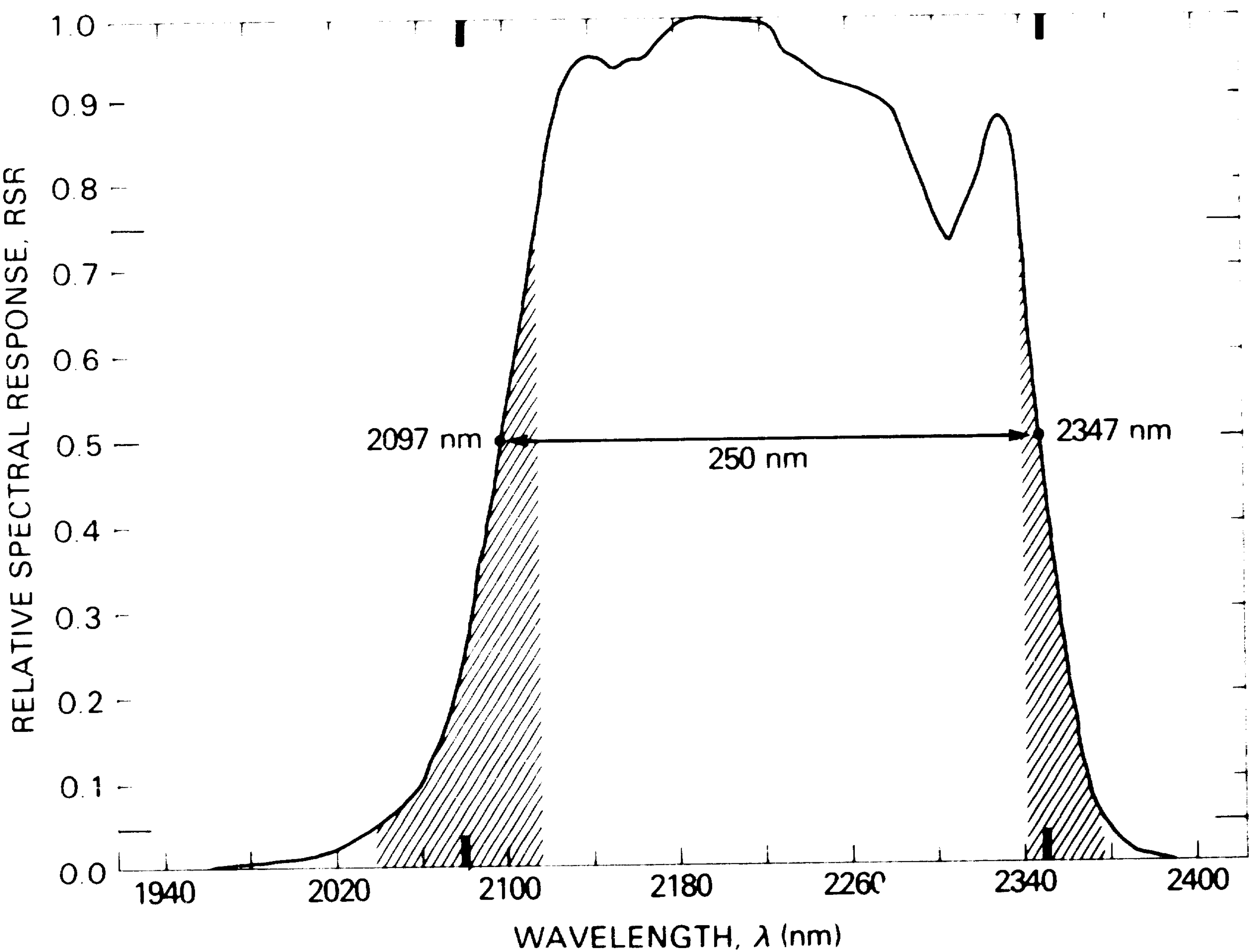
BAND 4/CHANNEL 23
(SBRC - JUNE 18, 1981)

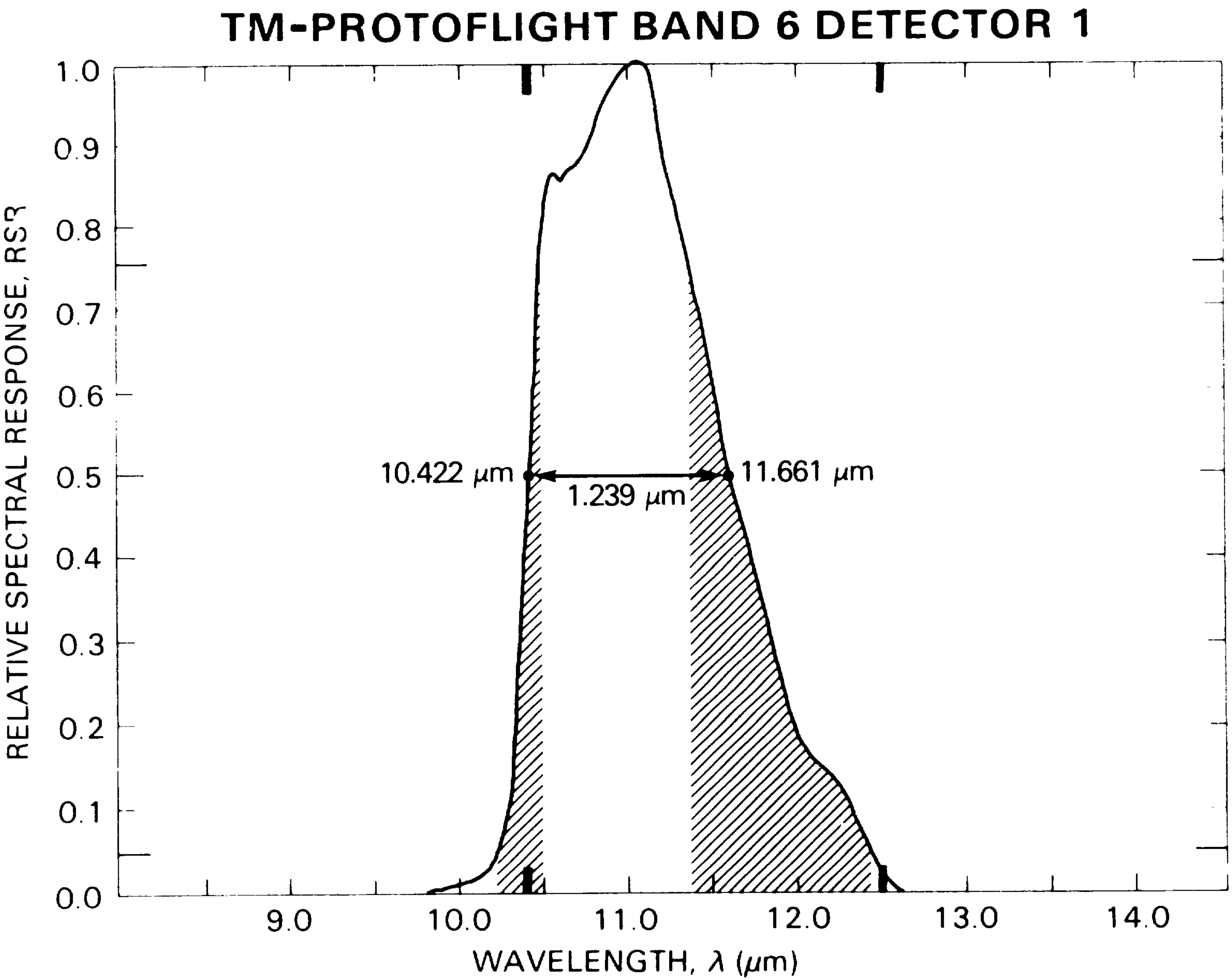




TM-PROTOFLIGHT BAND 5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
RELATIVE SPECTRAL RESPONSE, RSR
1568 nm
216 nm
1784 nm
1500
1580
1660
1740
1820
1900
WAVELENGTH, λ (nm)

TM-PROTOFLIGHT BAND 7





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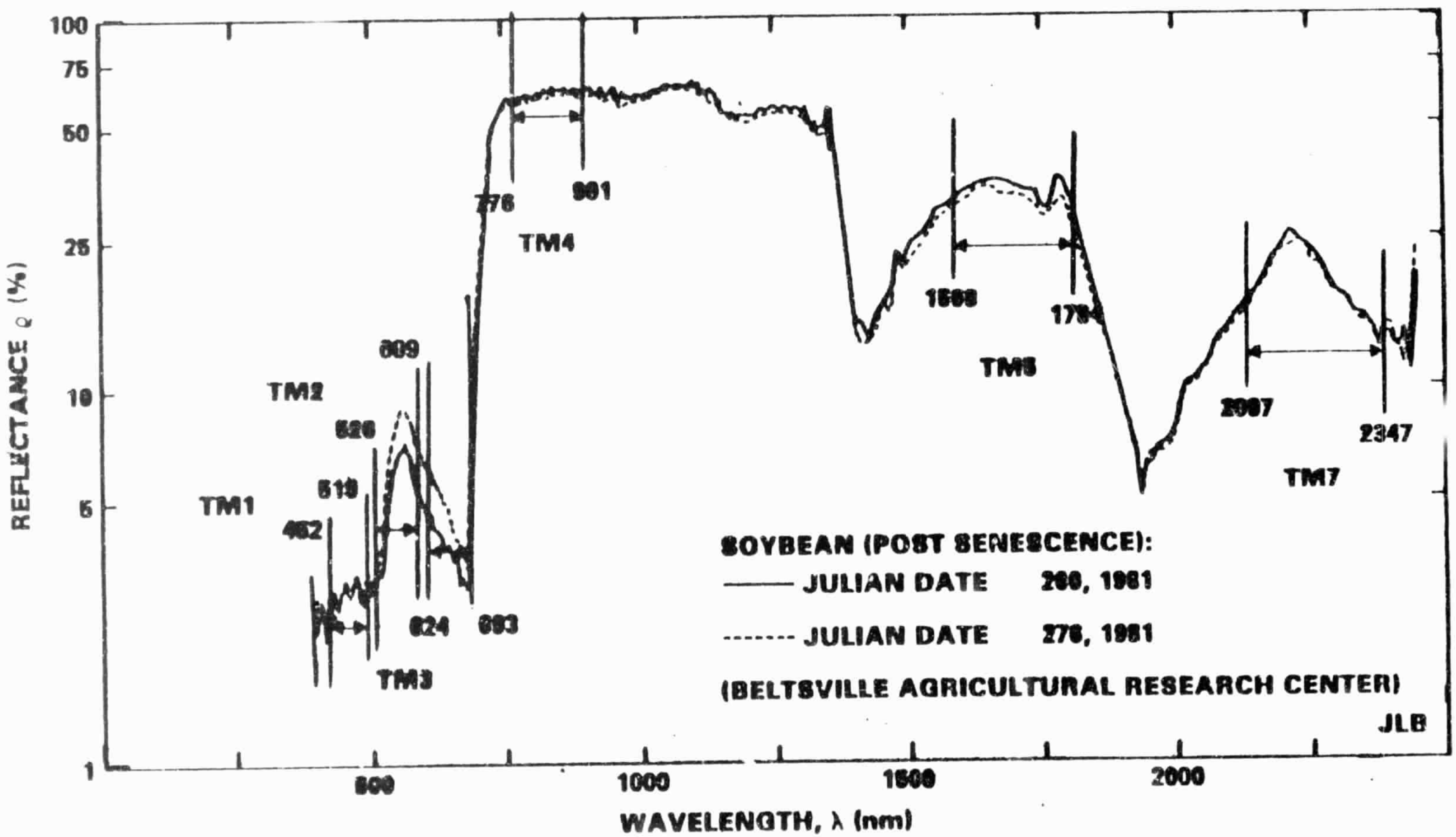
GROUND REFLECTANCE SPECTRA WITH LANDSAT-4 TM/PF BAND LOCATIONS



TM/PF RADIOMETRY
SPECTRAL INFORMATION
SUMMARY

SYSTEM LEVEL RSR CURVES WERE CALCULATED BY SBRC BASED ON MEASURED VALUES AT THE COMPONENT LEVEL

ABSOLUTE CALIBRATION

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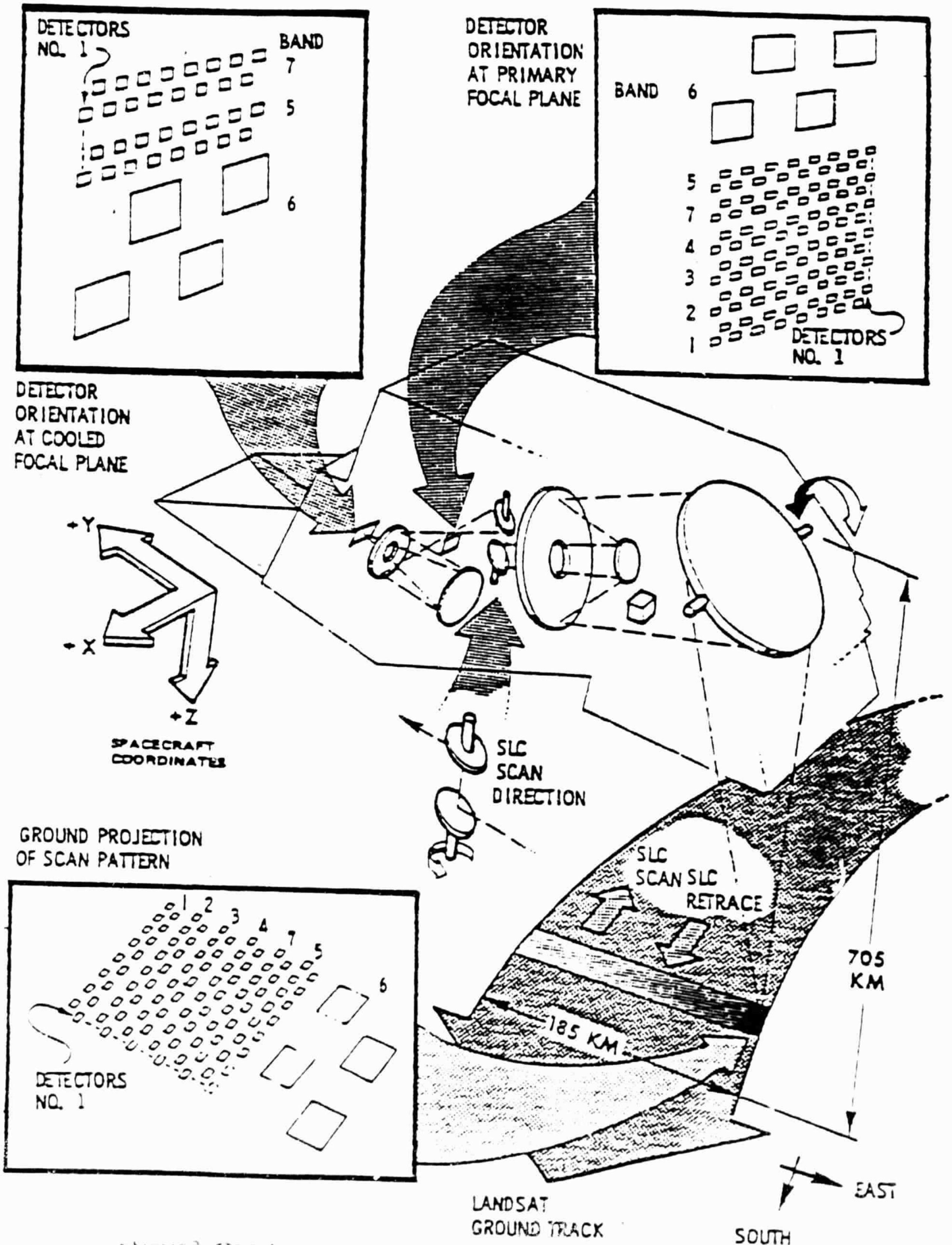
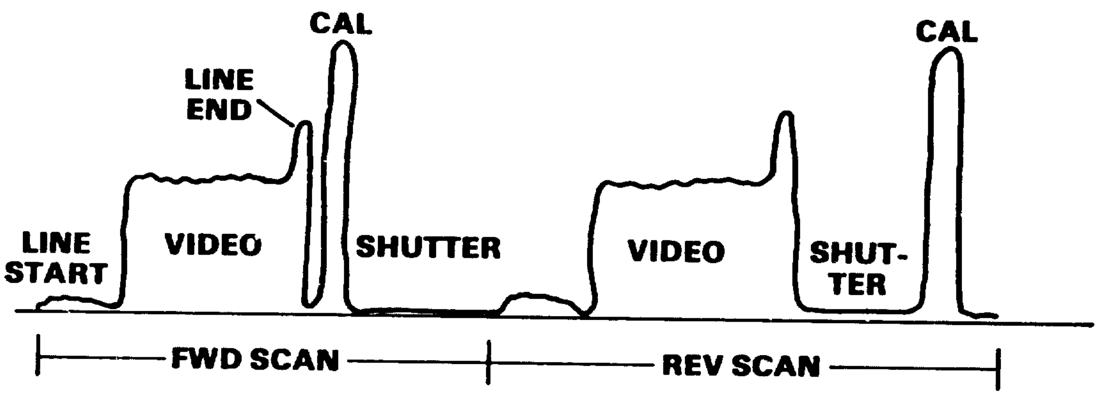


REPRESENTATION OF TM TIME SEQUENCE



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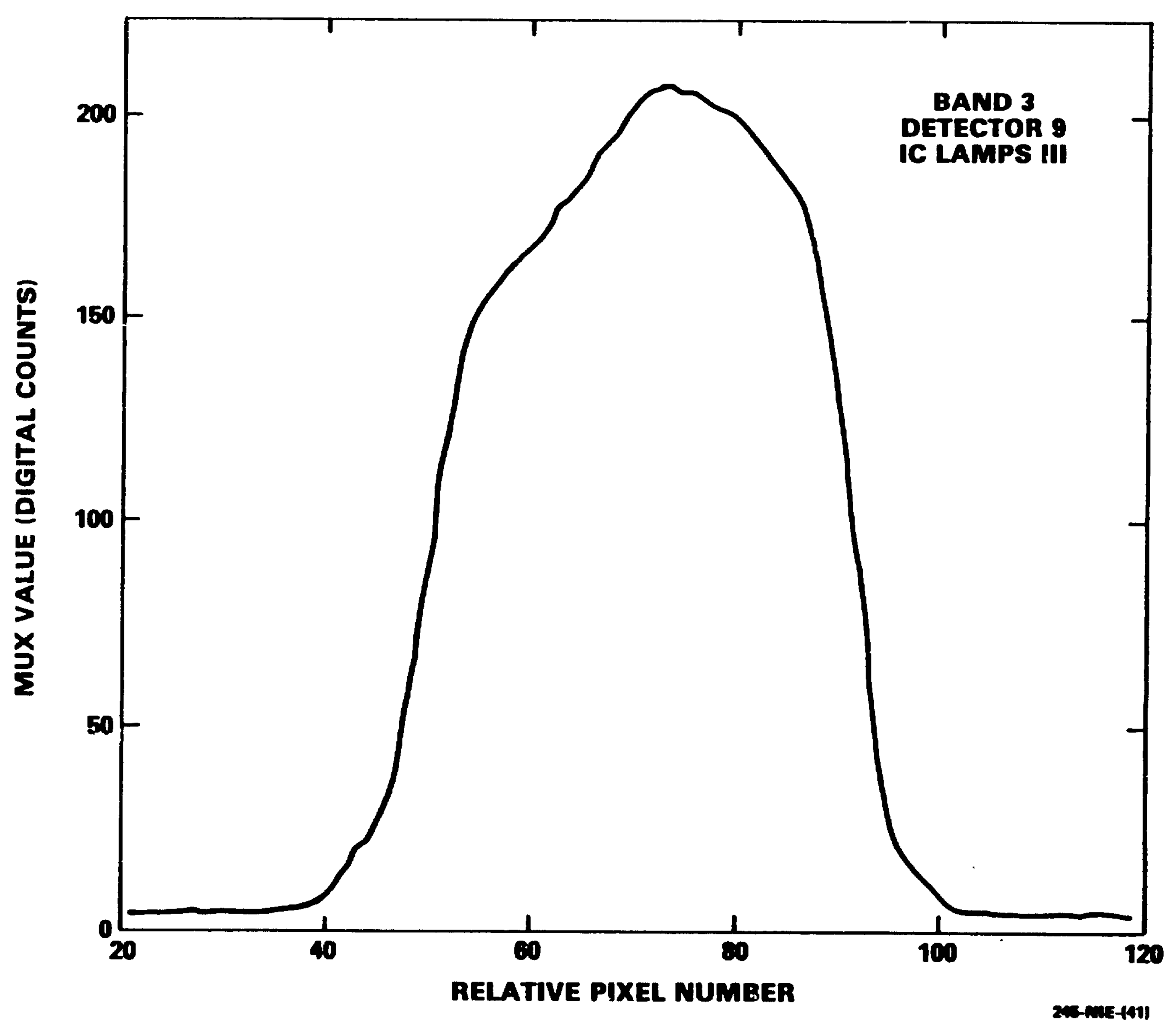
TYPICAL TM/PF CALIBRATION PULSE



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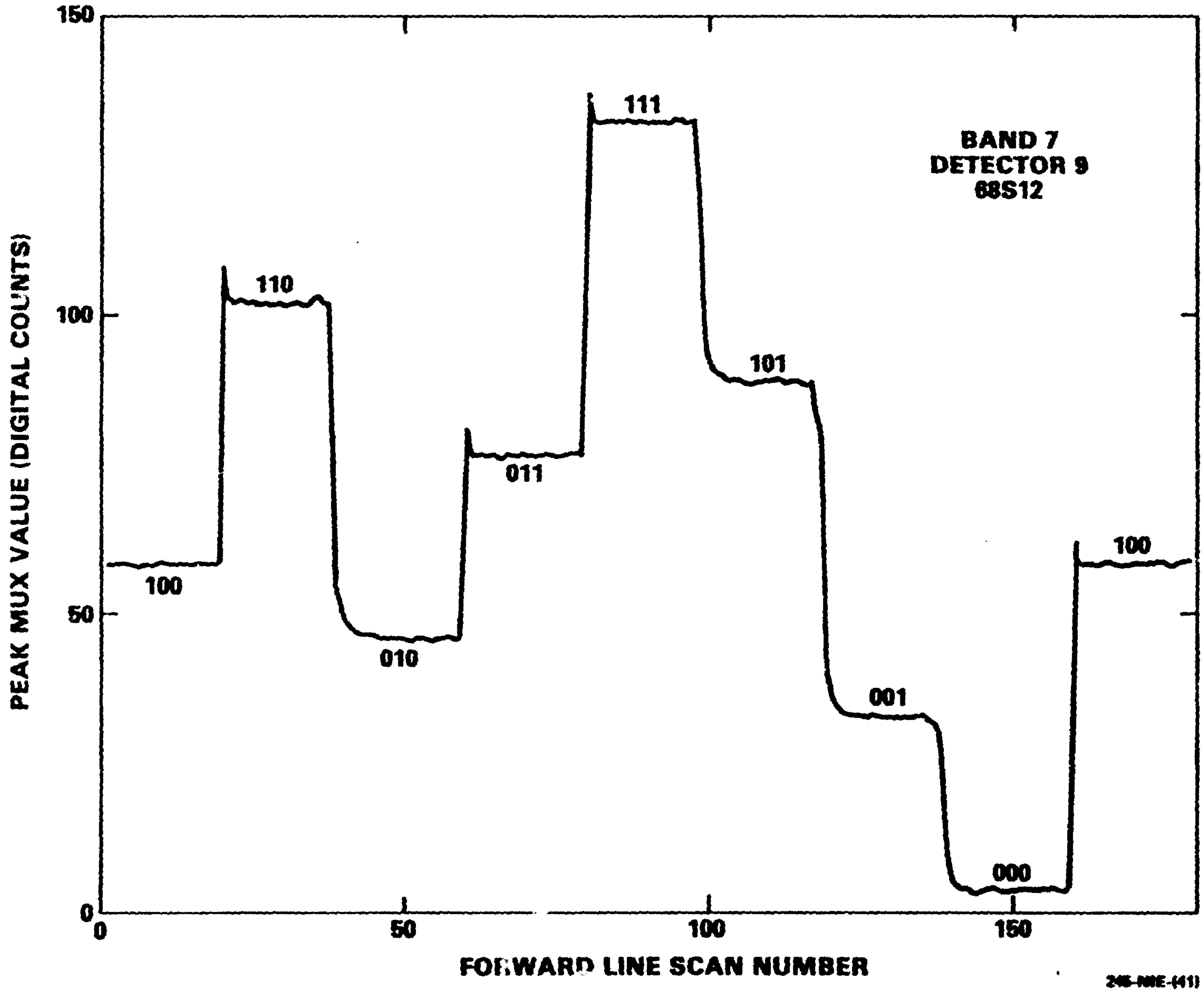
TM/PF INTERNAL CALIBRATOR LAMP SEQUENCE SHOWING LAMP OVERSHOOT AND THERMAL RELAXATION



ABSOLUTE CALIBRATION

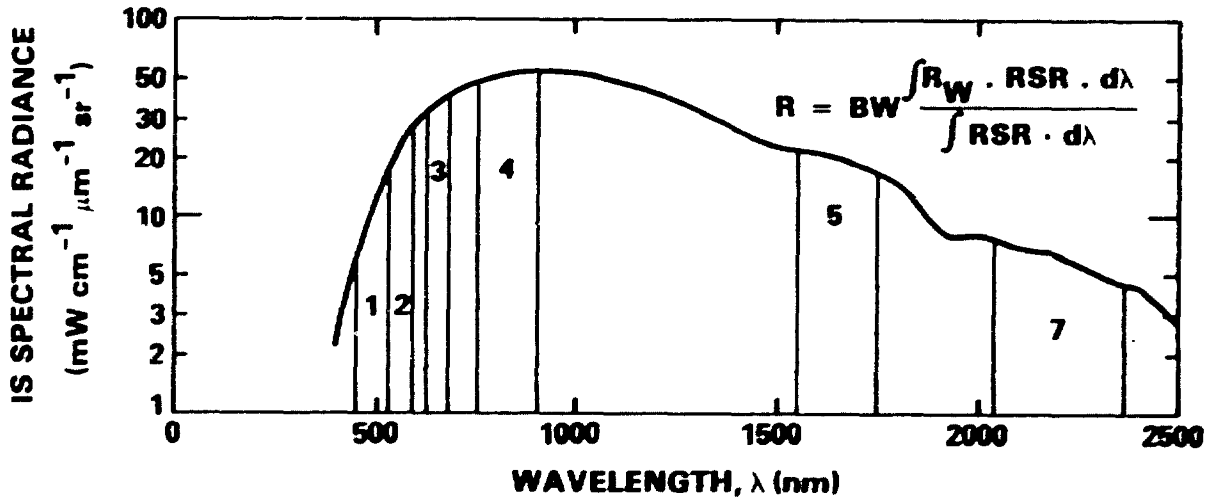
OVERVIEW OF PROCEDURE

DATES FOR THE 6 INTEGRATING SPHERE TESTS

TEST NUMBER	TIME	COMMENTS
1	2300 PDT - 29 JUNE 1981	T(CFPA) = -179.8^{o} CELSIUS
2	0600 PDT - 30 JUNE 1981	T(CFPA) = -168.5^{o} CELSIUS
3	1500 EST - 3 NOVEMBER 1981	NO BANDS 5 AND 7 (HS236-7881)
4	1700 EST - 19 MARCH 1982	MIRROR LOCKED IC AUTO (ON)
5	1200 EST - 19 MARCH 1982	MIRROR SCANNING IC AUTO (ON)
6	1400 EST - 19 MARCH 1982	MIRROR SCANNING IC BACKUP

PF = PROTO FLIGHT UNIT

TM/PF 122-cm INTEGRATING SPHERE SPECTRAL RADIANCE FOR ABSOLUTE RADIOMETRIC CALIBRATION



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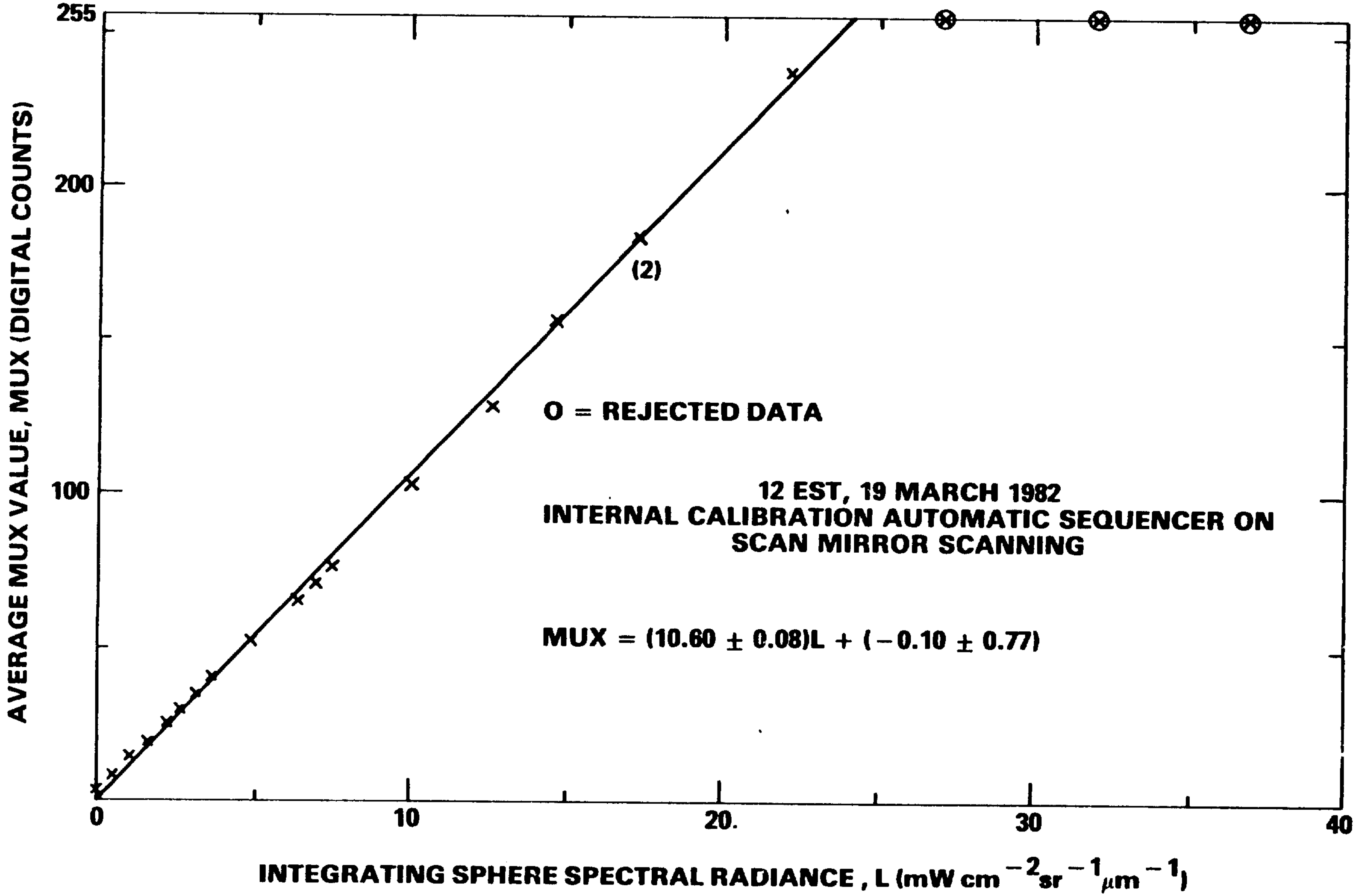
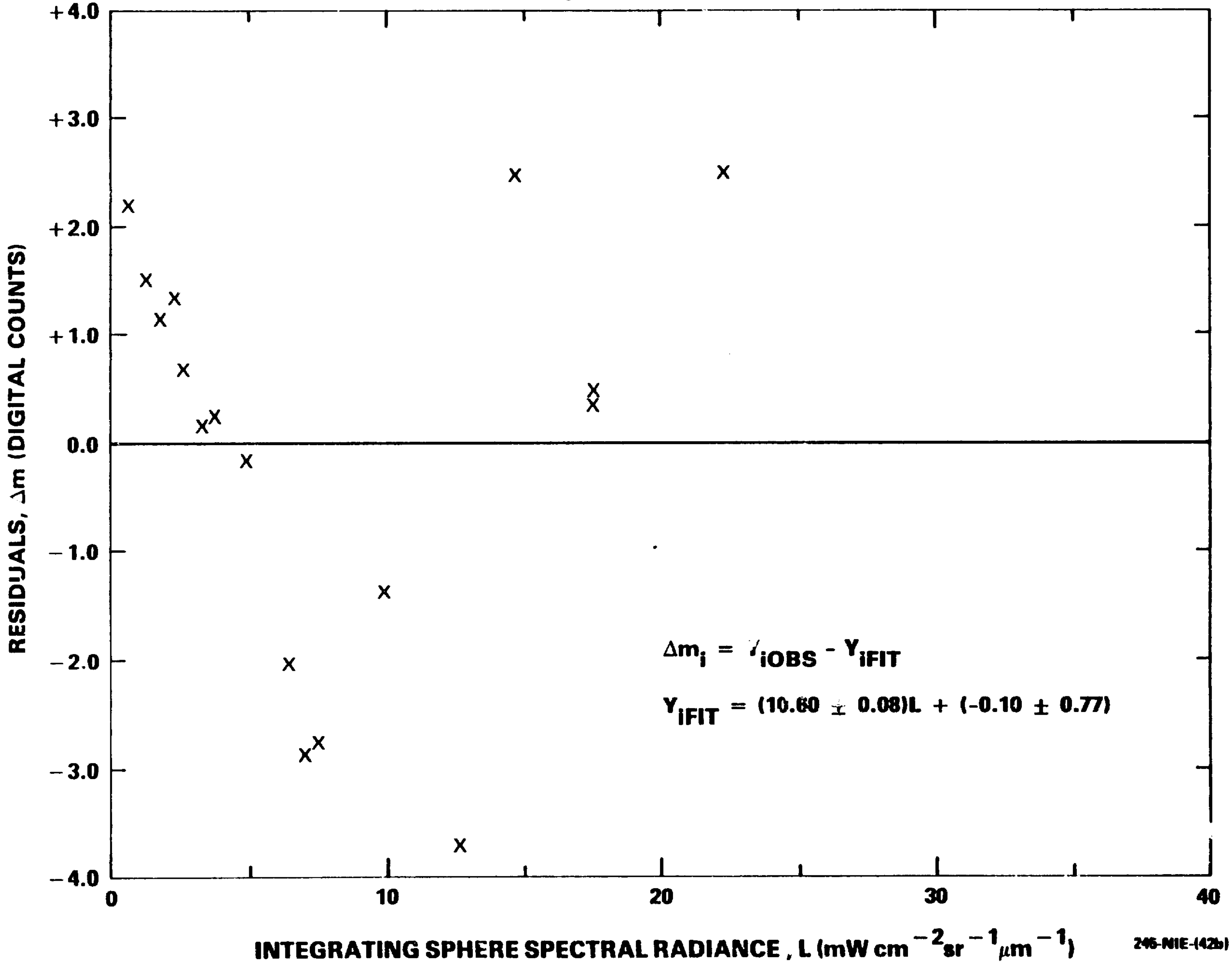
ILLUSTRATIVE TM/PF RADIOMETRIC ABSOLUTE DETECTOR CALIBRATION FOR CHANNEL 9 OF BAND 3 (624–693nm)



246-NIE-(42b)

ILLUSTRATIVE TM/PF RADIOMETRIC ABSOLUTE DETECTOR CALIBRATION FOR CHANNEL 9 OF BAND 3 (624–693nm)



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TYPICAL TM/PF DETECTOR RESPONSES (IN MUX UNITS) TEST NUMBER 5

RADIANCE LEVEL 13, 122cm INTEGRATING SPHERE

	BAND					
CHANNEL	TM1	TM2	TM3	TM4	TM5	TM7
1	24.40	26.92	53.00	76.02	220.43	134.63
2	23.62	26.28	51.66	74.13	220.83	132.80
3	24.10	26.06	51.96	75.57	*DEAD*	133.55
4	24.53	26.42	51.12	74.12	223.32	133.70
5	24.06	26.45	51.85	74.01	220.84	133.52
6	23.81	26.52	51.98	74.95	221.13	132.86
7	23.79	26.06	51.56	74.62	222.65	133.48
8	24.08	26.25	51.08	74.35	222.07	131.57
9	23.97	26.13	51.82	74.33	221.34	133.74
10	24.01	26.15	51.35	77.10	221.28	131.13
11	23.68	26.00	51.19	73.90	223.41	132.96
12	24.16	26.03	51.77	74.61	223.55	134.05
13	23.78	26.24	51.93	75.50	223.14	132.07
14	23.62	26.43	51.99	74.80	222.16	133.87
15	23.89	26.48	52.51	73.75	222.53	132.05
16	23.70	26.03	51.16	74.36	223.59	134.47
μ	23.95	26.28	51.75	74.76	222.15	133.15
σ	0.27	0.25	0.52	0.89	1.11	1.02
CV	1.11	0.94	1.00	1.20	0.50	0.76
NOMINAL SPECTRAL RADIANCE ($mW\ cm^{-2}\ sr^{-1}\ \mu m^{-1}$)	1.48	3.22	4.92	6.89	2.78	0.88

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DEFINITION OF STATISTICAL QUANTITIES

$$\mu = \frac{\Sigma x_i}{N}$$

$$\mu = \left(\frac{(\Sigma x_i^2) - (\Sigma x_i)^2/N}{N - 1} \right)^{1/2}$$

$$CV = \frac{\sigma}{\mu} \times 100 \text{ (IN PERCENT)}$$

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TM/PF DETECTOR OFFSETS (IN MUX UNITS) FOR BAND 7

ALL INTEGRATING SPHERE TESTS*

DETECTOR		TEST 1	2	3	4	5	6
	1	3.83	3.95	--	3.67	3.70	3.72
	2	1.86	1.99	--	3.03	3.11	3.07
	3	3.10	3.21	--	3.06	3.12	3.13
	4	1.95	2.12	--	3.10	3.17	3.19
	5	3.11	3.26	--	2.93	3.02	3.03
	6	2.09	2.20	--	3.13	3.20	3.22
	7	3.86	3.50	--	2.90	3.03	3.05
	8	1.61	1.77	--	3.06	3.11	3.16
	9	2.88	3.04	--	3.00	3.09	3.07
	10	1.35	1.55	--	3.12	3.18	3.21
	11	3.07	3.19	--	2.97	3.06	3.05
	12	1.93	2.06	--	3.20	3.24	3.34
	13	2.83	2.89	--	2.81	2.90	2.88
	14	2.47	2.64	--	3.28	3.32	3.43
	15	2.86	3.02	--	2.79	2.89	2.88
	16	2.40	2.55	--	3.29	3.32	3.38
BAND STATISTICS	μ	2.57	2.68	--	3.08	3.16	3.18
	σ	0.74	0.68	--	0.21	0.19	0.21

*SPHERE RADIANCE IS ASSUMED TO BE CONSTANT FOR ALL TESTS

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OBJECTIVE

SUMMARIZE GAIN CALIBRATION OF
ALL 96 DETECTORS FOR LATEST DATE

TM/PF DETECTOR GAINS (MUX/mW cm^{-2} sr^{-1} μm^{-1}) FOR BAND 1

ALL INTEGRATING SPHERE TESTS*

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		TEST 1	2	3	4	5	6
DETECTOR	1	16.490	16.473	15.750	15.962	15.640	15.635
	2	16.405	16.497	15.880	15.891	15.755	15.733
	3	16.770	16.762	16.060	16.057	15.921	15.912
	4	16.721	16.712	16.070	16.093	15.921	15.982
	5	16.612	16.612	15.950	15.910	15.803	15.798
	6	16.490	16.468	15.900	15.862	15.726	15.701
	7	16.481	16.469	15.870	15.798	15.678	15.671
	8	16.567	16.545	15.960	15.896	15.748	15.752
	9	16.645	16.643	16.040	15.936	15.817	15.814
	10	16.645	16.640	16.080	16.008	15.852	15.861
	11	16.526	16.514	15.910	15.814	15.679	15.882
	12	16.596	16.590	16.010	15.950	15.808	15.837
	13	16.546	16.531	15.920	15.821	15.687	15.682
	14	16.492	16.489	15.960	15.857	15.751	15.729
	15	16.647	16.633	16.030	15.936	15.775	15.777
	16	16.674	16.656	16.060	15.985	15.365	15.820
BAND STATISTICS	μ	16.588	16.577	15.966	15.910	15.777	15.787
	σ	0.090	0.093	0.092	0.095	0.086	0.096
	CV	0.543	0.561	0.576	0.597	0.545	0.608

*SPHERE RADIANCE IS ASSUMED TO BE CONSTANT FOR ALL TESTS

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TM/PF DETECTOR AVERAGE GAIN CHANGES*

ALL INTEGRATING SPHERE TESTS

BAND	TEST 1	2	3	4	5	6
1	51	51	12	8	0	0
2	12	10	-12	-3	0	-6
3	8	5	-18	-3	0	-5
4	42	43	41	6	0	1
5	24	17	--	-2	0	-1
7	21	25	--	0	0	-1

* GAIN CHANGES IN PARTS PER THOUSAND $\left(1000 \dfrac{X_{OBS} - X_{REF}}{X_{REF}}\right)$
REFERENCED TO TEST NUMBER 5
SPHERE RADIANCE IS ASSUMED TO BE CONSTANT FOR ALL TESTS

TM/PF DETECTOR RADIOMETRIC <u>GAINS</u> (MUX/(mW cm^{-2} sr^{-1} μm^{-1})) FOR TEST NUMBER 5

RADIANCE SOURCE: 122cm INTEGRATING SPHERE

CHANNEL NUMBER	BAND TM1	TM2	TM3	TM4	TM5	TM7
1	15.640	8.113	10.731	10.936	78.878	150.312
2	15.755	8.057	10.556	10.780	79.147	148.825
3	15.921	7.954	10.544	10.982	*DEAD*	149.762
4	15.921	8.083	10.486	10.795	80.042	149.792
5	15.803	8.135	10.578	10.776	79.122	149.798
6	15.726	8.122	10.617	10.896	79.207	148.744
7	15.678	7.996	10.536	10.778	79.747	149.886
8	15.748	8.018	10.480	10.842	79.494	147.385
9	15.817	8.015	10.599	10.824	79.287	149.982
10	15.852	8.032	10.521	11.253	79.280	146.774
11	15.679	7.938	10.495	10.717	80.008	149.034
12	15.808	7.954	10.597	10.864	80.100	150.005
13	15.687	8.053	10.638	11.018	79.894	148.192
14	15.751	8.080	10.593	10.875	79.588	149.837
15	15.775	8.133	10.722	10.735	79.641	148.247
16	15.865	7.920	10.439	10.792	80.087	150.572
NIS	20	20	17	14	8	11
μ	15.777	8.038	10.571	10.866	79.568	149.197
σ	0.086	0.071	0.082	0.134	0.412	1.095
CV	0.545	0.883	0.776	1.233	0.518	0.734

NIS = NUMBER OF INTEGRATING SPHERE RADIANCE LEVELS USED FOR GAIN/OFFSET

OBJECTIVE

REPRODUCIBILITY OF ABSOLUTE CALIBRATION FOR ALL BANDS

CONCLUSIONS

- REPRODUCIBILITY OF MEASUREMENT OF GIVEN DATA IS BETTER THAN 1% FOR ALL BANDS
- DIFFERENCES FROM JUNE 81 TO MARCH 82 WERE:
  - 5% IN TM1
  - 4% IN TM4
  - 2% IN TM5 AND TM7
  - 1% IN TM2 AND TM3

TM/PF DETECTOR RADIOMETRIC <u>OFFSETS</u> (IN MUX UNITS) FOR TEST NUMBER 5

RADIANCE SOURCE: 122CM INTEGRATING SPHERE

CHANNEL NUMBER	BAND TM1	TM2	TM3	TM4	TM5	TM7
1	1.44	1.35	0.46	1.30	2.90	3.70
2	0.64	0.69	-0.06	0.73	2.56	3.11
3	0.88	0.79	0.26	0.73	*DEAD*	3.12
4	0.81	0.80	-0.16	0.61	2.47	3.17
5	0.91	0.78	-0.05	0.55	2.62	3.02
6	0.76	0.89	-0.02	0.73	2.65	3.20
7	0.84	0.70	-0.08	1.00	2.63	3.03
8	0.81	0.89	-0.09	0.61	2.76	3.11
9	0.88	0.76	-0.10	0.67	2.65	3.09
10	0.71	0.71	-0.14	0.47	2.54	3.18
11	0.78	0.75	-0.15	0.72	2.66	3.06
12	0.75	0.72	-0.15	0.57	2.50	3.24
13	0.82	0.74	-0.21	0.43	2.72	2.90
14	0.68	0.83	0.02	0.69	2.57	3.32
15	0.83	0.73	-0.13	0.49	2.76	2.90
16	0.61	0.82	0.02	0.78	2.59	3.32
NIS	20	20	17	14	8	11
μ	0.82	0.81	-0.04	0.69	2.64	3.16
σ	0.19	0.16	0.17	0.22	0.11	0.19

NIS = NUMBER OF USEABLE INTEGRATING SPHERE RADIANCE LEVELS FOR GAIN/OFFSET DETERMINATION

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TM/PF CHANNEL OFFSET (DIGITAL COUNTS) STANDARD DEVIATIONS

ALL INTEGRATING SPHERE TESTS*

		TEST					
		1	2	3	4	5	6
BAND	1	0.342	0.340	--	0.188	0.187	0.184
	2	0.165	0.167	--	0.152	0.157	0.161
	3	0.199	0.198	--	0.240	0.172	0.194
	4	0.220	0.212	--	0.211	0.215	0.217
	5	1.084	1.046	--	0.101	0.113	0.094
	7	0.745	0.683	--	0.213	0.192	0.215

* SPHERE RADIANCE IS ASSUMED TO BE CONSTANT FOR ALL TESTS

TM/PF INTERNAL TEMPERATURES DURING ABSOLUTE RADIOMETRIC CALIBRATION

	TIME	EVEN AMB PA TEMP	SI FPA TEMP	CAL LP FLT TEMP	CLD PAMP TEMP	CLD ST FPA TEMP	TEST INDEX
29 JUNE	23:32:04	30.18	21.22	17.14	17.45	-179.74	
	23:39:41	33.92	21.89	17.45	18.07	-179.94	
30 JUNE	02:29:56	34.62	21.09	17.45	18.39	-177.24	F
PDT	03:03:05	28.86	20.82	17.14	16.83	-177.14	F
MIRROR	04:26:44	31.18	21.08	19.01	17.76	-177.24	F
LOCKED	06:12:06	30.51	21.62	17.76	17.45	-168.54	
	06.21:07	33.92	22.43	17.76	18.39	-168.44	
	06.55.33	30.18	21.89	17.76	17.45	-168.94	F
	07:20:49	29.51	21.62	18.08	17.45	-169.24	F
19 MARCH	9:55:57	28.85	26.33	23.08	14.04	-177.	
EST	10:01:54	32.87	26.94	23.39	14.35	-177.	D
MIRROR	10:43:28	43.51	29.98	24.66	16.52	-177.	D
SCANNING	12:12:39	30.17	27.72	24.34	14.66	-177.	E
TEST 5	12:31:54	39.81	29.32	24.98	16.21	-178.	E

TM INTERNAL CALIBRATION (IC) SYSTEM

- SCHEMATIC TM
- IC LAMPS AND FIBER OPTICS
- IC SHUTTER MECHANISM
- IC SHUTTER
- PRIMARY FOCAL PLANE GEOMETRY

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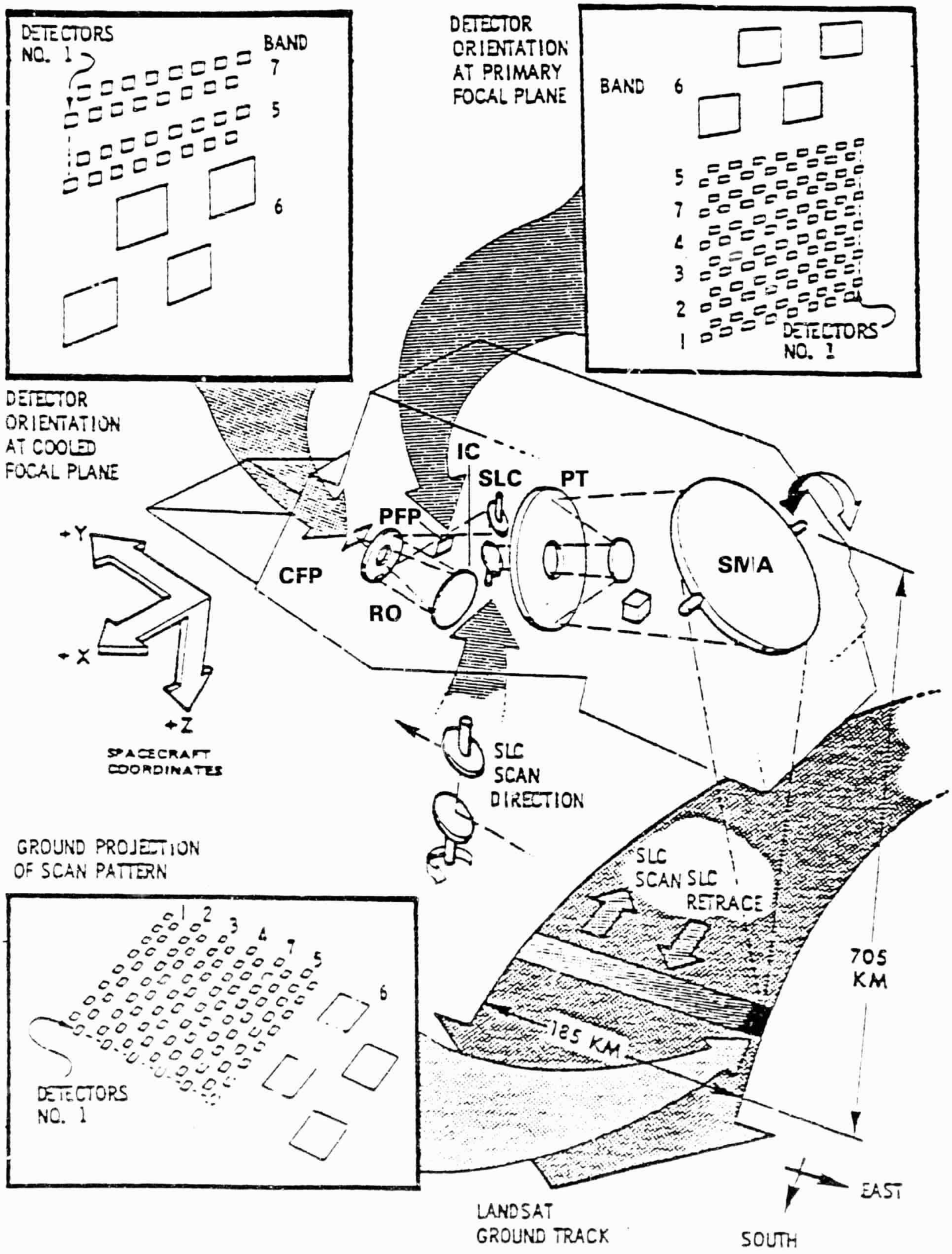
DETECTOR ORIENTATION AT PRIMARY FOCAL POINT



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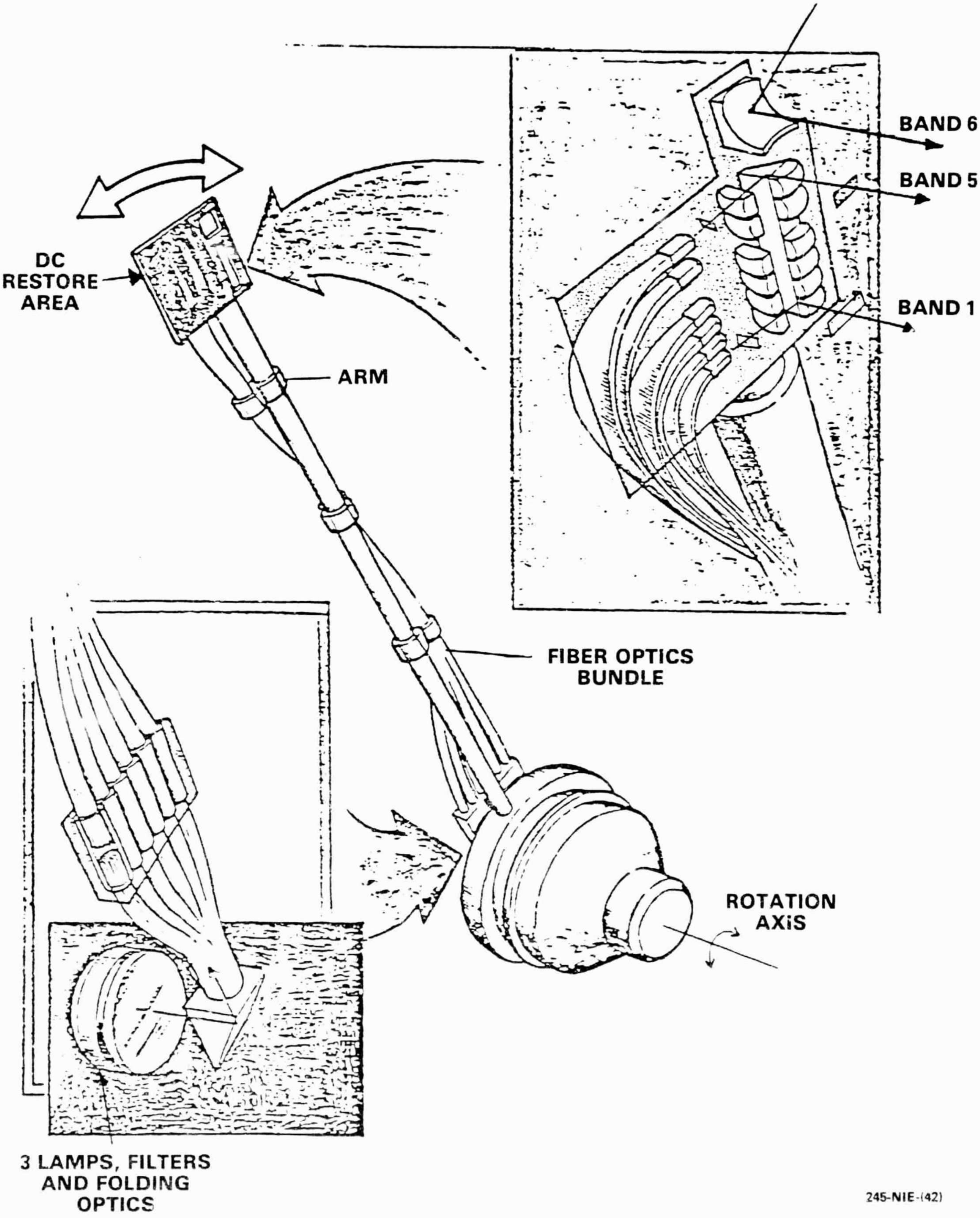
OVERVIEW OF THE INTERNAL CALIBRATOR



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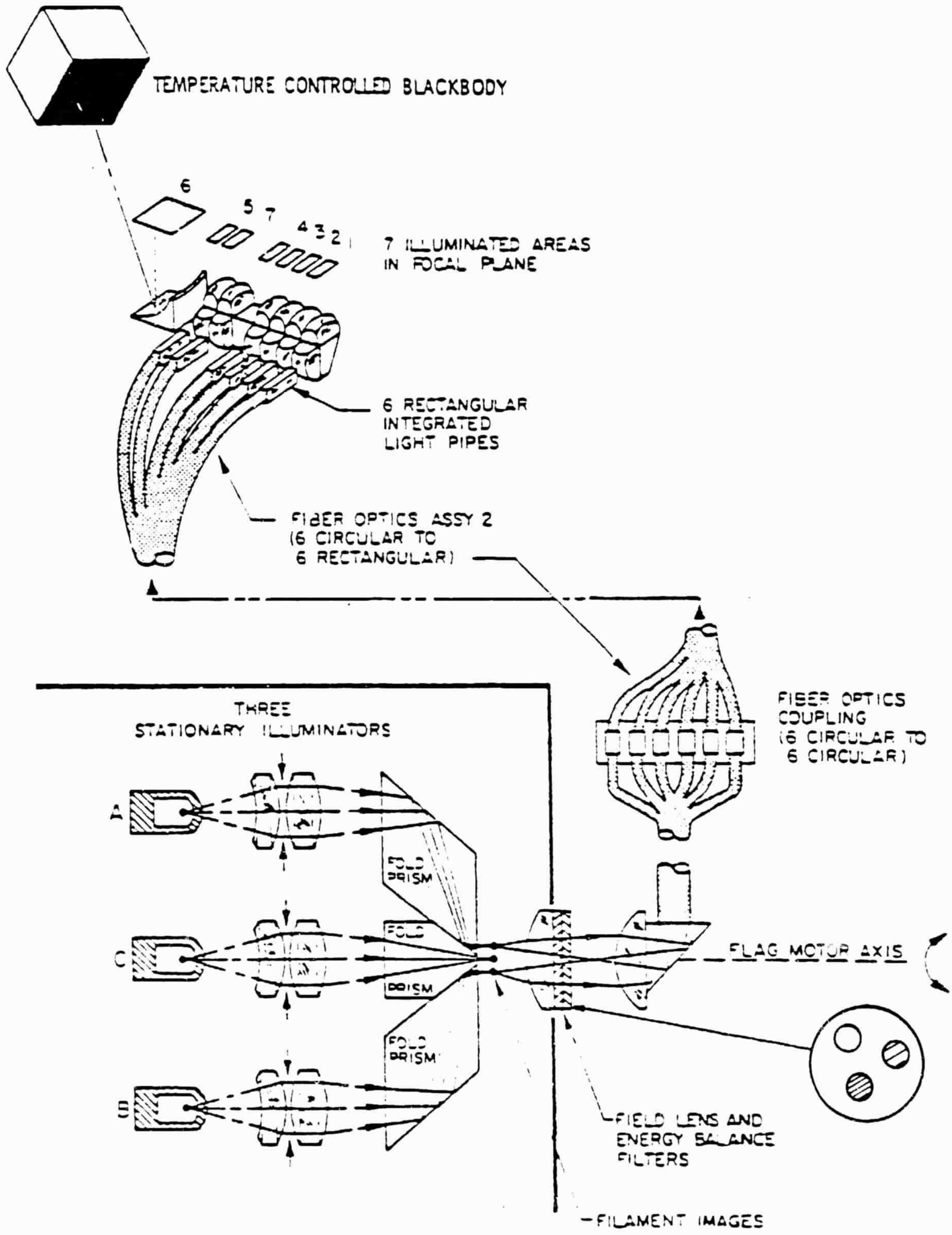
DETAILS OF THE INTERNAL CALIBRATOR OPTICAL SYSTEM



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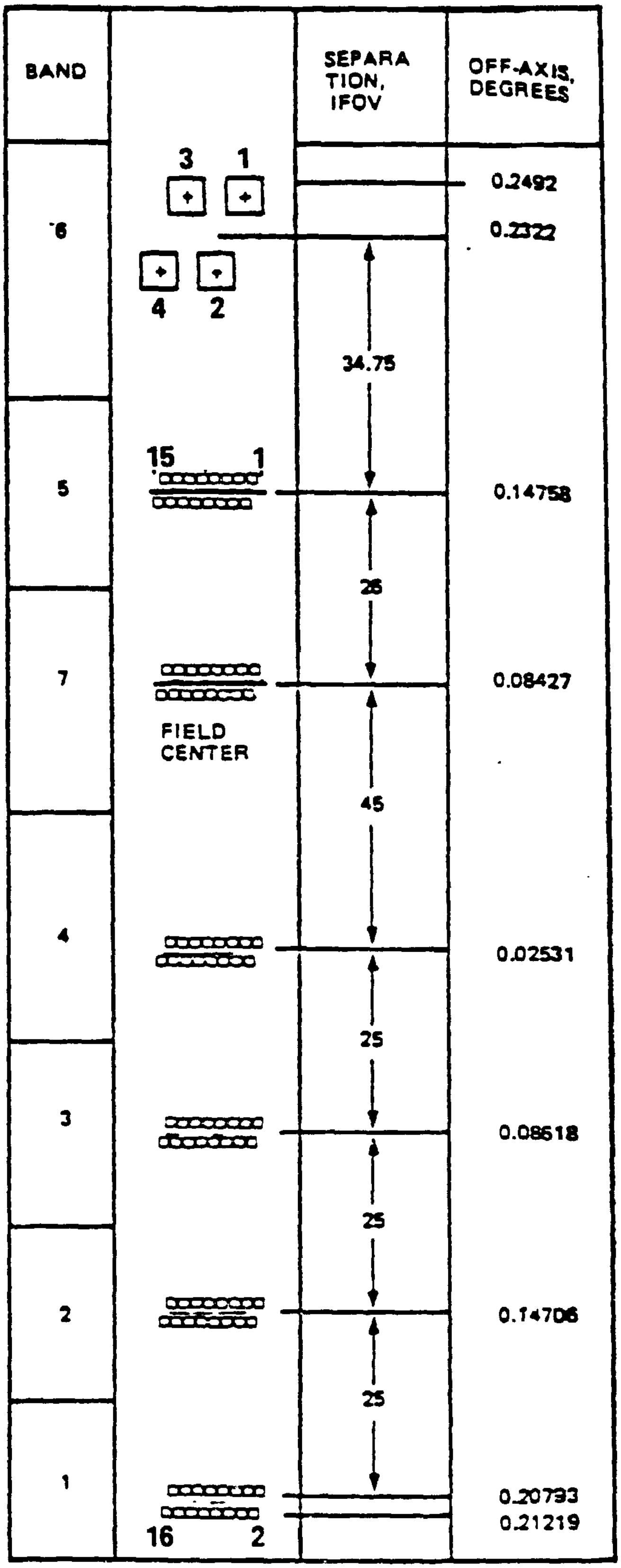
DETECTOR PROJECTION AT PRIME FOCAL PLANE
(NOT TO SCALE)



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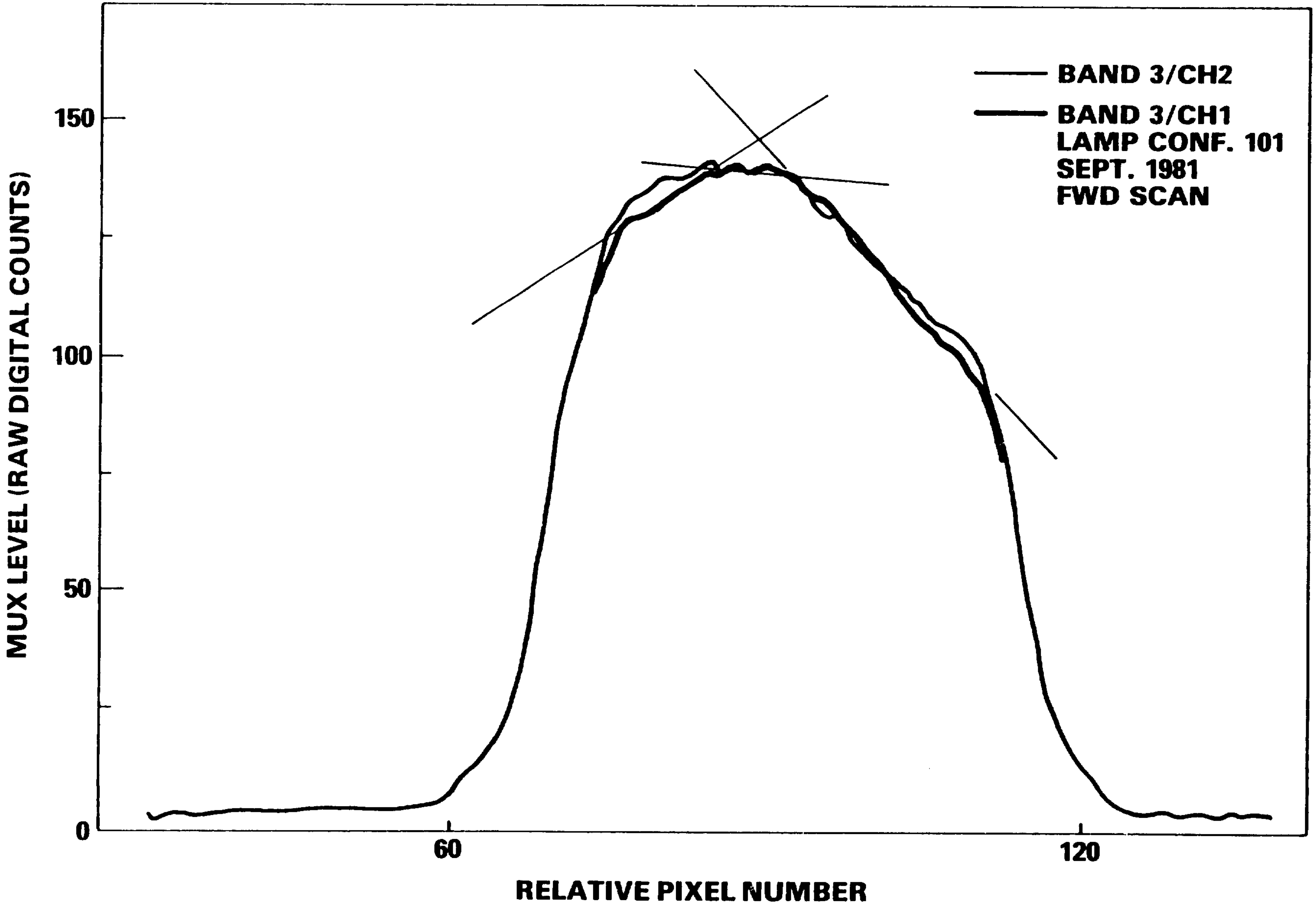
ABSOLUTE CALIBRATION OF
INTERNAL LAMPS

COMPARISON OF CALIBRATION PROFILES BETWEEN CHANNELS



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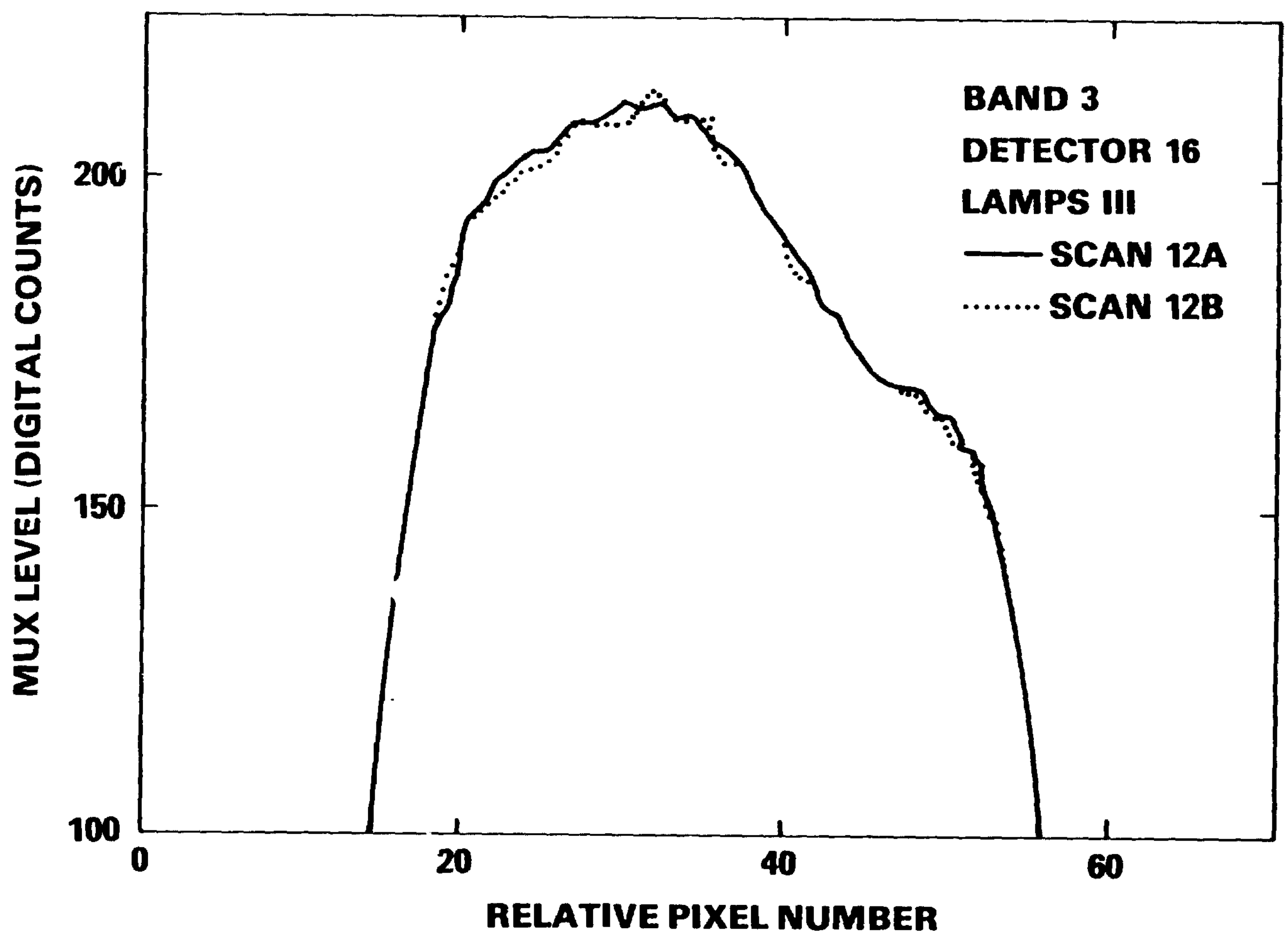
COMPARISON OF CALIBRATION PROFILES BETWEEN FORWARD AND REVERSE SCANS



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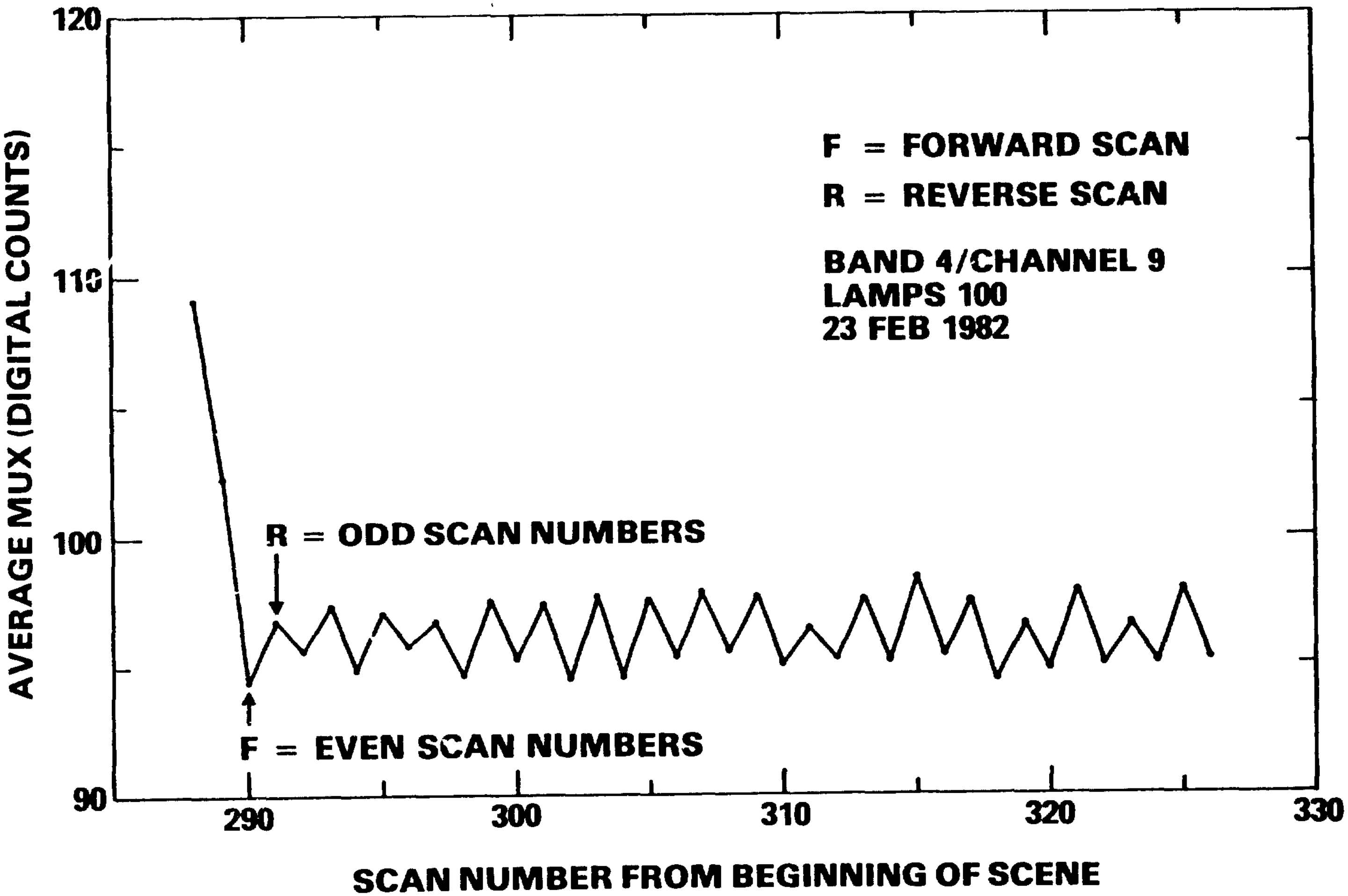
SBRC CAL VALUE EXTRACTION

ALGORITHM

- FIND PEAK VALUE WITHIN THE 160 PIXEL SEARCH WINDOW
- FIND FIRST AND LAST PIXELS WHOSE VALUE EXCEEDS 40 PERCENT OF PEAK VALUE
- DETERMINE PULSE CENTER AS MEAN OF THESE TWO PIXEL POSITIONS
- AVERAGE THE CENTRAL 31 PIXELS ABOUT THE PULSE CENTER

TM/PF CALIBRATION PULSE INTEGRATED VALUES (IN MUX UNITS)



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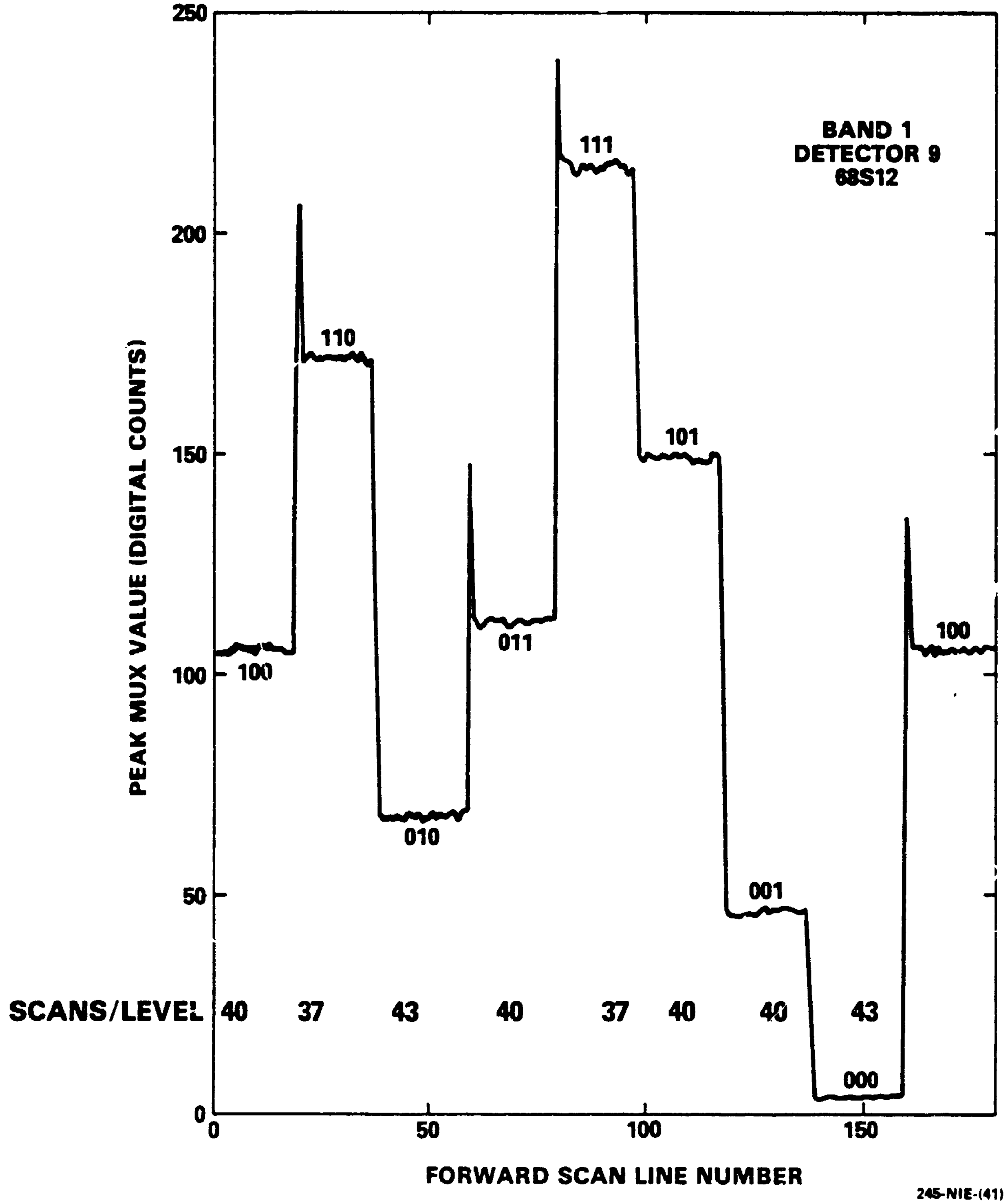
TM/PF INTERNAL CALIBRATOR LAMP SEQUENCE SHOWING LAMP TURNON OVERSHOOT



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SELF-CONSISTENCY CHECK OF DETECTOR CALIBRATION
TRANSFERENCE TO IC LAMPS IN MUX UNITS
FOR BAND 1, DETECTOR 9

IC LAMP	TEST 1	2	3	4	5	6
SUM CHECK						
SUM1	-1.632	-0.819	+0.222	+0.154	-0.151	+0.64
SUM2	-0.090	+15.019	+0.044	+0.376	-0.900	-0.67
SUM3	-0.216	+0 190	+0.780	+0.050	+1.014	+0.44

SUM1 = 110 - 100 - 010 + 000
SUM2 = 101 - 100 - 001 + 000
SUM3 = 011 - 010 - 001 + 000

THREE EQUIVALENT METHODS OF CHECKING CONSISTENCY

CONCLUSION:

IC CHECKS ARE CONSISTENT FOR TM1 TO WITHIN 1 DIGITAL COUNT EXCEPT IN JUNE 1981 TESTS

OBJECTIVE:

ILLUSTRATIVE SUMMARY OF LAMP CALIBRATION DATA FOR 6 BANDS X 16 CHANNELS X 8 LAMP CONFIGURATIONS

NOTE:

IC ABSOLUTE CALIBRATION DATA WERE TAKEN SUBSEQUENT TO DETECTOR COLLECTS FROM INTEGRATING SPHERE, THEREFORE, CALIBRATION OF LAMPS ASSUMES CONSTANCY OF DETECTOR GAIN AND OFFSET.

TRANSFER OF TM/PF DETECTOR CALIBRATION TO INTERNAL CALIBRATOR (IC) LAMPS

(21:29 EST, 20 MARCH 1982)

DETECTOR 9

IC LAMP CONFIGURATION	BAND TM1	TM2	TM3	TM4	TM5	TM7
100	6.629	12.462	8.509	8.375	0.549	0.374
110	10.851	22.124	14.639	14.639	1.052	0.672
010	4.312	9.824	6.358	8.721	0.504	0.294
011	7.161	15.494	9.916	12.809	0.790	0.506
111	13.659	27.624	18.085	20.746	[illegible]	0.880
101	9.505	18.168	12.076	12.381	0.830	0.581
001	2.952	5.823	2.777	4.242	0.282	0.205
000	0.100	0.176	0.230	0.140	0.003	0.005

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IC SPECTRAL RADIANCES (mW cm^{-2} sr^{-1} μm^{-1}) USING TEST 4 GAINS/OFFSETS

*LAMP CONFIGURATION INDICATES WHICH LAMPS ARE ON (E.G., 100 = LAMP A ON, LAMPS B, C OFF)

TRANSFER OF TM/PF DETECTOR CALIBRATION TO INTERNAL CALIBRATOR (IC) LAMPS

(21:29 EST, 20 MARCH 1982)

DETECTOR 12

IC LAMP CONFIGURATION	BAND TM1	TM2	TM3	TM4	TM5	TM7
100	6.590	11.281	8.795	8.952	0.810	0.364
110	10.559	19.130	15.318	16.762	1.523	0.724
010	4.150	8.039	6.767	8.078	0.715	0.355
011	6.829	12.925	10.619	12.478	1.112	0.579
111	13.317	23.935	10.063	21.065	1.916	0.942
101	9.310	16.158	12.633	13.270	1.208	0.585
001	2.877	5.059	4.066	4.584	0.399	0.217
000	0.072	0.180	0.225	0.140	0.003	0.006

IC SPECTRAL RADIANCES ($mW\ cm^{-2}\ sr^{-1}\ \mu m^{-1}$) USING TEST 4 GAINS/OFFSETS

ASSUMPTIONS IN ABSOLUTE CALIBRATION PROCEDURE

ABSOLUTE SPHERE RADIANCE IS CONSTANT AND KNOWN

COLOR TEMPERATURE IS CONSTANT FOR ALL IS LEVELS

GAIN AND OFFSET OF DETECTORS ARE CONSTANT

- DURING INTEGRATING SPHERE COLLECTS
- BETWEEN DATES

PULSE SHAPE IS THE SAME IN AMBIENT AND VACUUM

SHUTTER BACKGROUND IS RANDOM

TM6 THERMAL BAND ABSOLUTE CALIBRATION

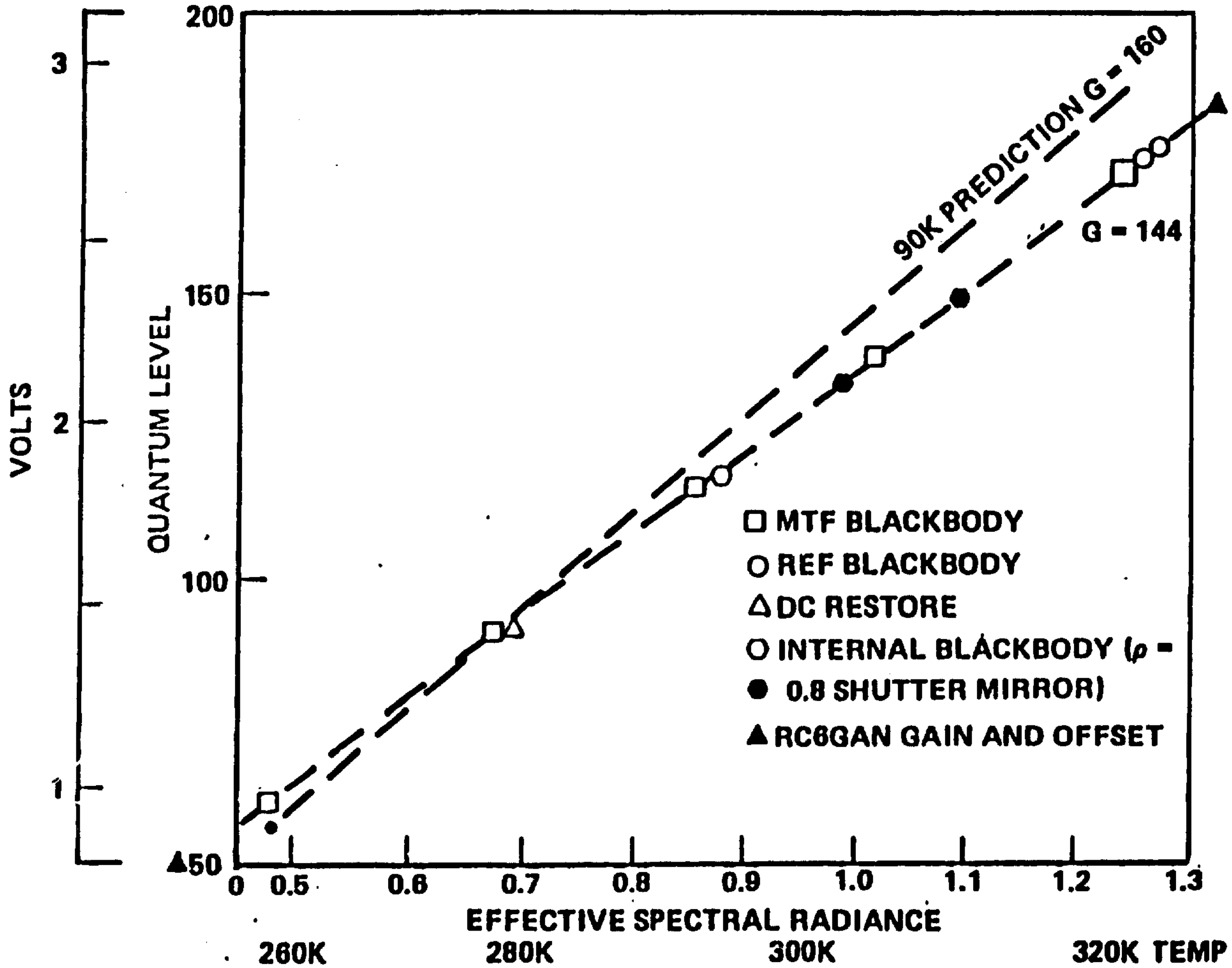
DATA COLLECTED

MODELS AND CONSTANTS TO BE DETERMINED

THEMATIC MAPPER

PROTOFLIGHT BAND 6
GAIN-LINEARITY DATA
FIGURE 2/96K CFP TEMP 24 AUG 1981

HUGHES



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NOISE CHARACTERIZATION

OBJECTIVE:

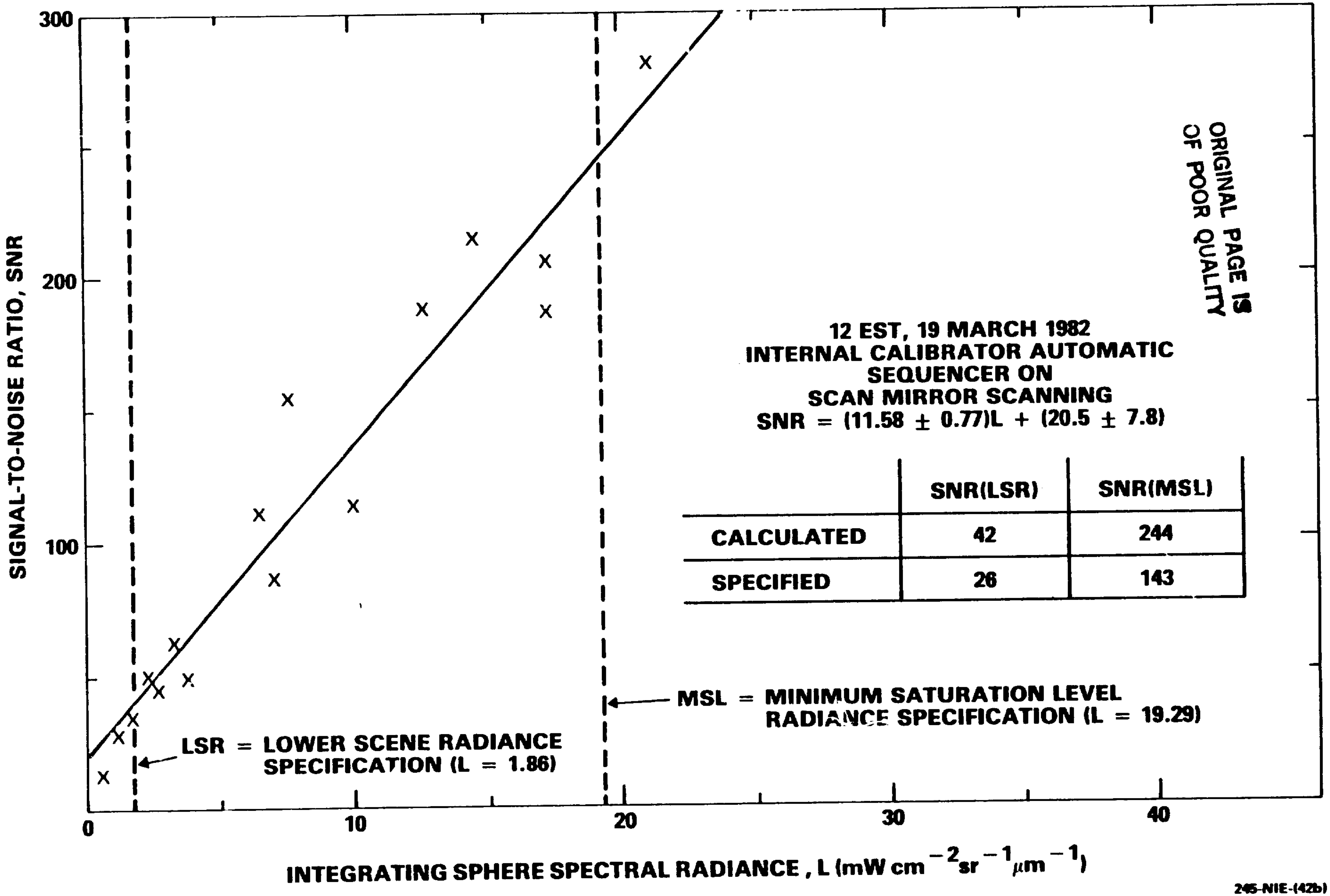
CHARACTERIZE REPRODUCIBILITY OF NOISE AT MAXIMUM AND MINIMUM RADIANCE

CONCLUSION:

- REPRODUCIBLE ON DIFFERENT DATES (BASED ON TM1)
- NOISE WITHIN A BAND IS RELATIVE CONSTANT
- BAND HAS DIFFERENT AVERAGE NOISE

	1	2	3	4	5	7
LOW	1.0	.4	.6	.4	.9	1.0
HIGH	1.6	1.0	1.0	.7	1.4	1.1

ILLUSTRATIVE TM/PF RADIOMETRIC ABSOLUTE DETECTOR SIGNAL-TO-NOISE MEASUREMENTS FOR CHANNEL 9 OF BAND 3 (624-693nm)



	SNR(LSR)	SNR(MSL)
CALCULATED	42	244
SPECIFIED	26	143

TM/PF HIGH SIGNAL NOISE VALUES* (IN MUX UNITS) FOR BAND 1

ALL INTEGRATING SPHERE TESTS

CHANNEL NO.	TEST 1	2	3	4	5	6
1	1.87	1.82	--	1.66	1.68	1.61
2	1.80	1.78	--	1.62	1.75	1.72
3	1.54	1.53	--	1.65	1.54	1.53
4	1.64	1.56	--	2.04	1.84	1.92
5	1.57	1.56	--	1.46	1.42	1.48
6	1.67	1.71	--	1.51	1.51	1.60
7	1.62	1.61	--	1.46	1.48	1.45
8	1.63	1.73	--	1.64	1.60	1.60
9	1.57	1.61	--	1.43	1.29	1.45
10	1.55	1.55	--	1.69	1.51	1.52
11	1.72	1.71	--	1.47	1.49	1.47
12	1.63	1.63	--	1.86	1.64	1.60
13	1.71	1.65	--	1.39	1.40	1.44
14	1.72	1.74	--	1.52	1.55	1.41
15	1.63	1.71	--	1.61	1.48	1.63
16	1.73	1.73	--	1.78	1.74	1.78
BAND STATISTICS μ	1.66	1.66	--	1.61	1.56	1.58
σ	0.03	0.09	--	0.17	0.13	0.14

*STANDARD DEVIATION OF HIGHEST OBSERVABLE RADIANCE (IN DIGITAL COUNTS)

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TM/PF LOW SIGNAL NOISE VALUES (IN MUX UNITS) FOR BAND 1

ALL INTEGRATING SPHERE TESTS

DETECTOR		TEST 1	2	3	4	5	6
	1	1.11	1.07	--	1.09	1.12	1.11
	2	1.05	1.07	--	1.21	1.17	1.17
	3	0.88	0.95	--	0.94	0.93	0.92
	4	1.00	1.01	--	1.58	1.54	1.44
	5	0.84	0.90	--	0.90	0.86	0.91
	6	0.89	0.92	--	0.96	0.96	1.04
	7	0.82	0.90	--	0.98	0.88	0.91
	8	0.89	0.88	--	1.03	1.07	1.07
	9	0.88	0.93	--	0.90	0.89	0.89
	10	0.78	0.86	--	1.05	1.01	1.02
	11	1.02	0.99	--	0.98	1.03	0.93
	12	0.82	0.86	--	1.32	1.29	1.27
	13	0.88	0.87	--	0.85	0.86	0.89
	14	0.99	0.97	--	1.01	1.01	1.05
	15	1.03	1.01	--	1.02	1.02	1.05
	16	0.99	1.02	--	1.15	1.13	1.18
BAND STATISTICS	μ	0.93	0.95	--	1.06	1.05	1.05
	σ	0.09	0.07	--	0.18	0.18	0.15

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TM/PF HIGH SIGNAL NOISE VALUES (IN MUX UNITS) FOR TEST NUMBER 5

CHANNEL	BAND					
NO.	TM 1	TM 2	TM 3	TM 4	TM 5	TM 7
1	1.68	1.04	1.27	0.87	1.33	0.48
2	1.75	1.39	0.98	0.78	1.22	1.34
3	1.54	0 88	1.02	0.87	*DEAD*	0.87
4	1.84	1.96	0.96	0.80	1.45	0.90
5	1.42	1.05	0.99	0.72	1.40	0.87
6	1.51	1.02	0.87	0.70	1.29	1.32
7	1.48	0.77	0.99	0.70	1.62	1.63
8	1.60	0.67	0.82	0.65	1.30	1.33
9	1.39	0.75	0.85	0.72	1.29	0.84
10	1.51	0.77	0.93	0.64	1.26	1.54
11	1.49	0.95	0.93	0.64	1.47	1.28
12	1.64	0.93	0.96	0.68	1.45	0.92
13	1.40	0.81	0.91	0.87	1.44	1.27
14	1.55	0.99	0.89	0.55	1.33	1.01
15	1.48	1.11	1.15	0.67	1.43	1.29
16	1.74	0.93	0.93	0.80	1.42	0.49
*N	11.39	24.47	22.12	19.78	2.78	1.66
μ	1.56	1.00	0.97	0.73	1.38	1.09
σ	0.13	0.31	0.11	0.09	0.10	0.34

*N IS SPECTRAL RADIANCE (mW CM^{-2} SR^{-1} μM^{-1}) OF HIGHEST INTEGRATING SPHERE LEVEL FOR WHICH THERE WAS DATA

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TM/PF LOW SIGNAL NOISE VALUES (IN MUX UNITS) TEST NUMBER 5 (MAR 82)

CHANNEL NO.	BAND TM 1	TM 2	TM 3	TM 4	TM 5	TM 7
1	1.12	0.50	0.53	0.42	0.91	0.92
2	1.17	1.06	0.53	0.45	0.84	1.01
3	0.93	0.40	0.56	0.25	*DEAD*	0.84
4	1.54	0.61	0.52	0.50	0.94	1.00
5	0.66	0.36	0.38	0.50	0.94	0.83
6	0.96	0.34	0.55	0.36	0.99	0.96
7	0.88	0.41	0.59	0.48	1.13	2.34
8	1.07	0.38	0.55	0.47	0.89	0.90
9	0.89	0.35	0.62	0.48	0.90	0.99
10	1.01	0.38	0.67	0.30	0.87	1.06
11	1.03	0.32	0.65	0.50	0.97	0.91
12	1.29	0.43	0.67	0.50	0.92	0.99
13	0.86	0.18	0.72	0.49	0.88	0.86
14	1.01	0.32	0.51	0.46	0.85	1.05
15	1.03	0.37	0.68	0.46	0.90	0.77
16	1.19	0.11	[illegible]	0.49	0.86	0.94
*N	0.18	0.38	0.58	0.79	0.31	0.09
μ	1.04	0.41	0.59	0.44	0.92	1.02
σ	0.20	0.21	0.09	0.08	0.07	0.36

*N IS THE SPECTRAL RADIANCE (mW cm^{-2} sr^{-1} μm^{-1}) OF LOWEST NON-DARK INTEGRATING SPHERE LEVEL FOR WHICH THERE WERE DATA

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TM/PF NOISE CHARACTERIZATION

BAND 1

CHANNEL NO.	MID-SCAN* RESPONSE		NOISE* PEAK-TO-PEAK RESPONSE	NOISE** PEAK-TO-PEAK RESPONSE	
	MEAN	STD. DEV.	TOTAL	32 KHz	6 KHz
1	66.47	±1.33	12	1.7	.9
2	65.73	±1.56	13	2.4	.3
3	67.00	±1.30	11	1.9	.6
4	66.48	±1.56	10	.9	.8
5	66.93	±1.26	11	1.9	.5
6	65.74	±1.52	11	2.7	.5
7	66.18	±1.20	10	1.5	.4
8	65.82	±1.37	10	2.2	.5
9	65.52	±1.15	9	1.3	.5
10	65.92	±1.24	10	1.0	.4
11	65.96	±1.33	11	2.0	.6
12	66.66	±1.45	12	1.1	.8
13	66.44	±1.25	10	1.8	.5
14	66.37	±1.46	11	2.5	.4
15	65.49	±1.32	11	2.0	.6
16	65.40	±1.81	14	3.7	.7

* 8MAR82 VERSION 325 FLOODING LAMP

** 8MAR82 DATA AT DIFFERENT TIME ANALYZED BY FAST FOURIER TRANSFORM

TM/PF NOISE CHARACTERIZATION (DIGITAL COUNTS)

BAND 2

CHANNEL NO.	MID-SCAN* RESPONSE		NOISE* PEAK-TO-PEAK RESPONSE	NOISE** PEAK-TO-PEAK RESPONSE	
	MEAN	STD. DEV.	TOTAL	32 KHz	6 KHZ
1	66.37	± .37	5	.2	.2
2	68.20	±1.07	10	.6	.2
3	65.69	± .55	5	.2	.2
4	65.69	± .64	6	.2	.0
5	67.65	± .61	6	.3	.1
6	66.29	± .62	6	.7	.1
7	66.04	± .54	5	.2	.1
8	65.13	± .56	4	.2	.2
9	66.17	± .55	5	.1	.1
10	64.90	± .56	5	.3	.1
11	65.64	± 55	5	.3	.2
12	64.78	± .57	6	.3	.2
13	68.99	± .52	5	.1	.2
14	65.44	± .58	6	.2	.1
15	66.84	± .74	5	.2	.2
16	63.54	± .77	6	.7	.2

* 8MAR82 VERSION 325 FLOODING LAMP

**FAST FOURIER TRANSFORM OF 8MAR82 DATA AT DIFFERENT TIME

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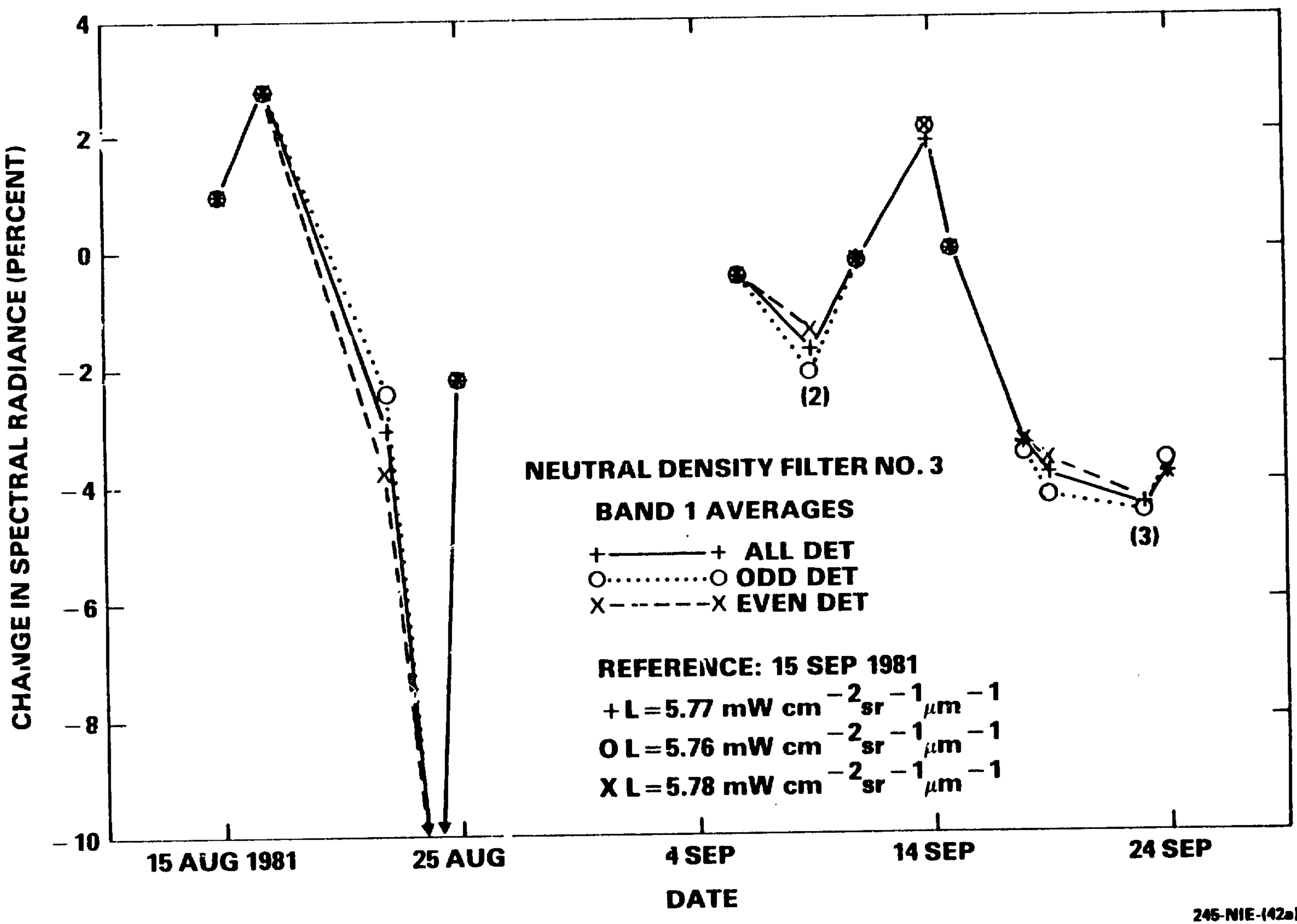
TM/PF NOISE CHARACTERIZATION

CONCLUSIONS

- SIGNAL-TO-NOISE EXCEEDS SPECIFICATIONS EXCEPT FOR CHANNEL 2 OF TM 2
- A SMALL FREQUENCY SPECIFIC COMPONENT OF NOISE HAS BEEN OBSERVED AND MEASURED IN BAND 1, 2, 3, AND 4

SENSOR HISTORY

SUMMARY OF
EL SEGUNDO THERMAL-VACUUM BASELINE TEST
TEST OF DETECTOR AND EXTERNAL CALIBRATOR STABILITY



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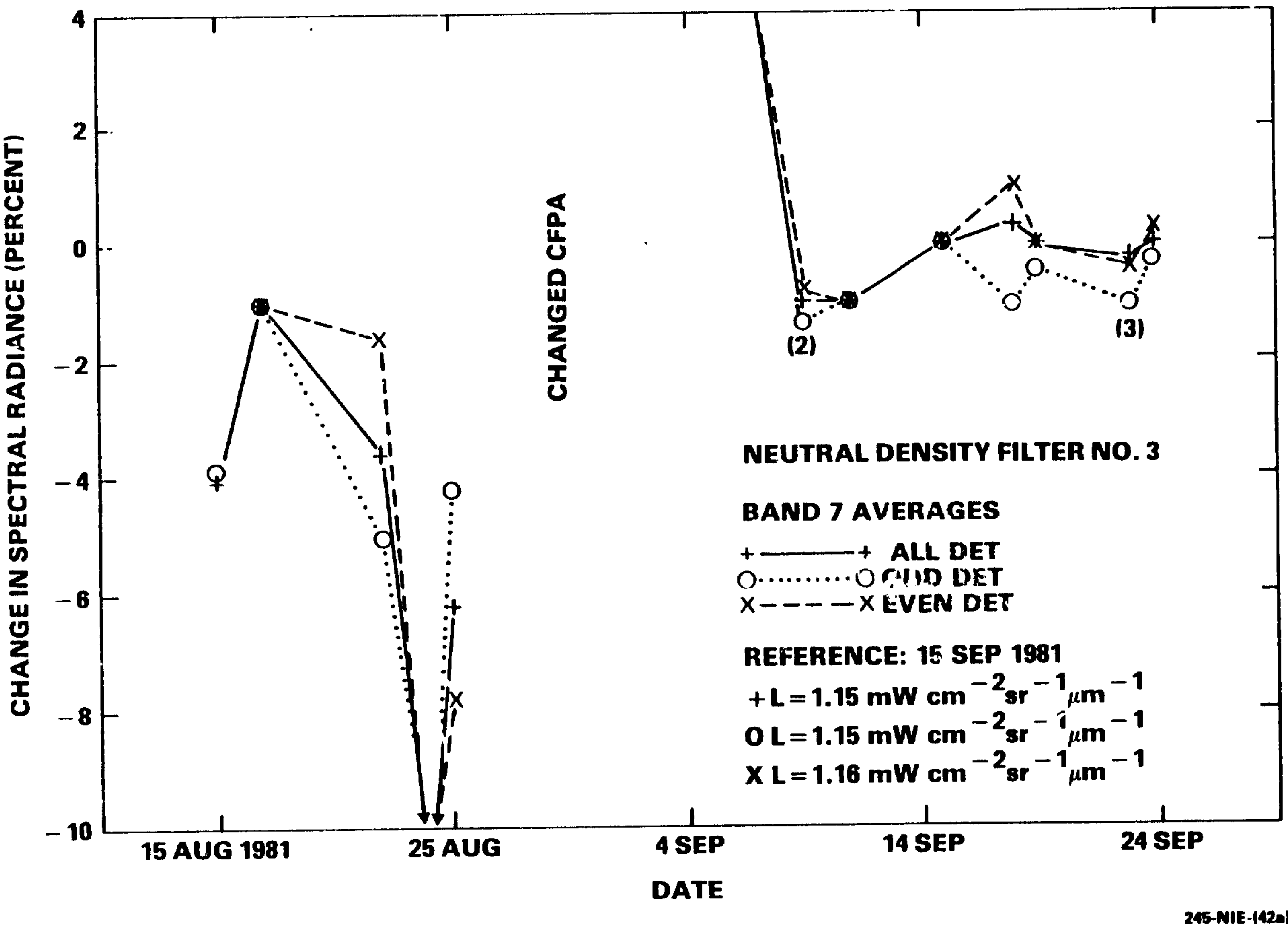
SUMMARY OF
EL SEGUNDO THERMAL-VACUUM BASELINE TEST
TEST OF DETECTOR AND EXTERNAL CALIBRATOR STABILITY



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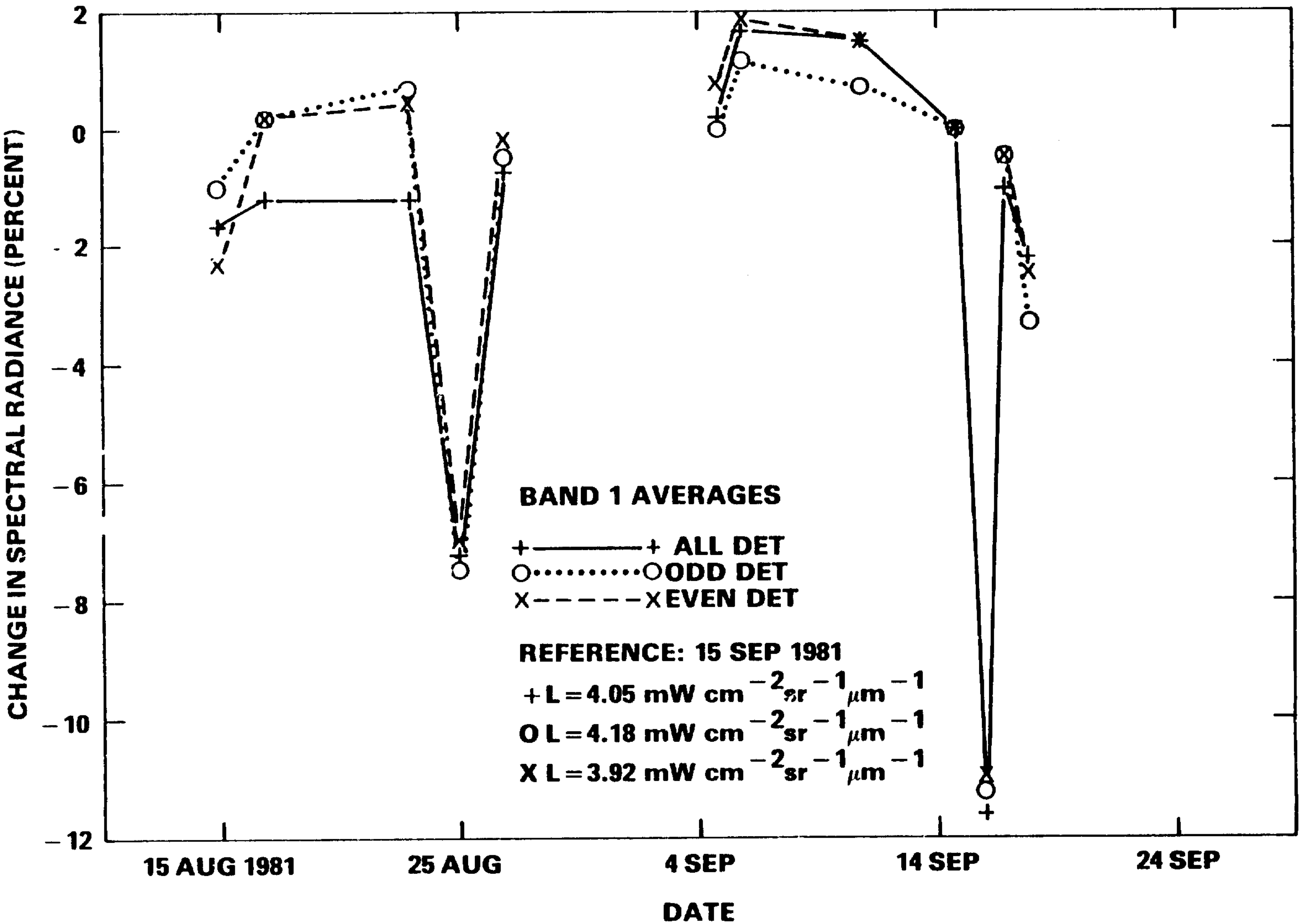
SUMMARY OF EL SEGUNDO THERMAL-VACUUM BASELINE TEST

TEST OF DETECTOR AND INTERNAL CALIBRATOR STABILITY



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SUMMARY OF
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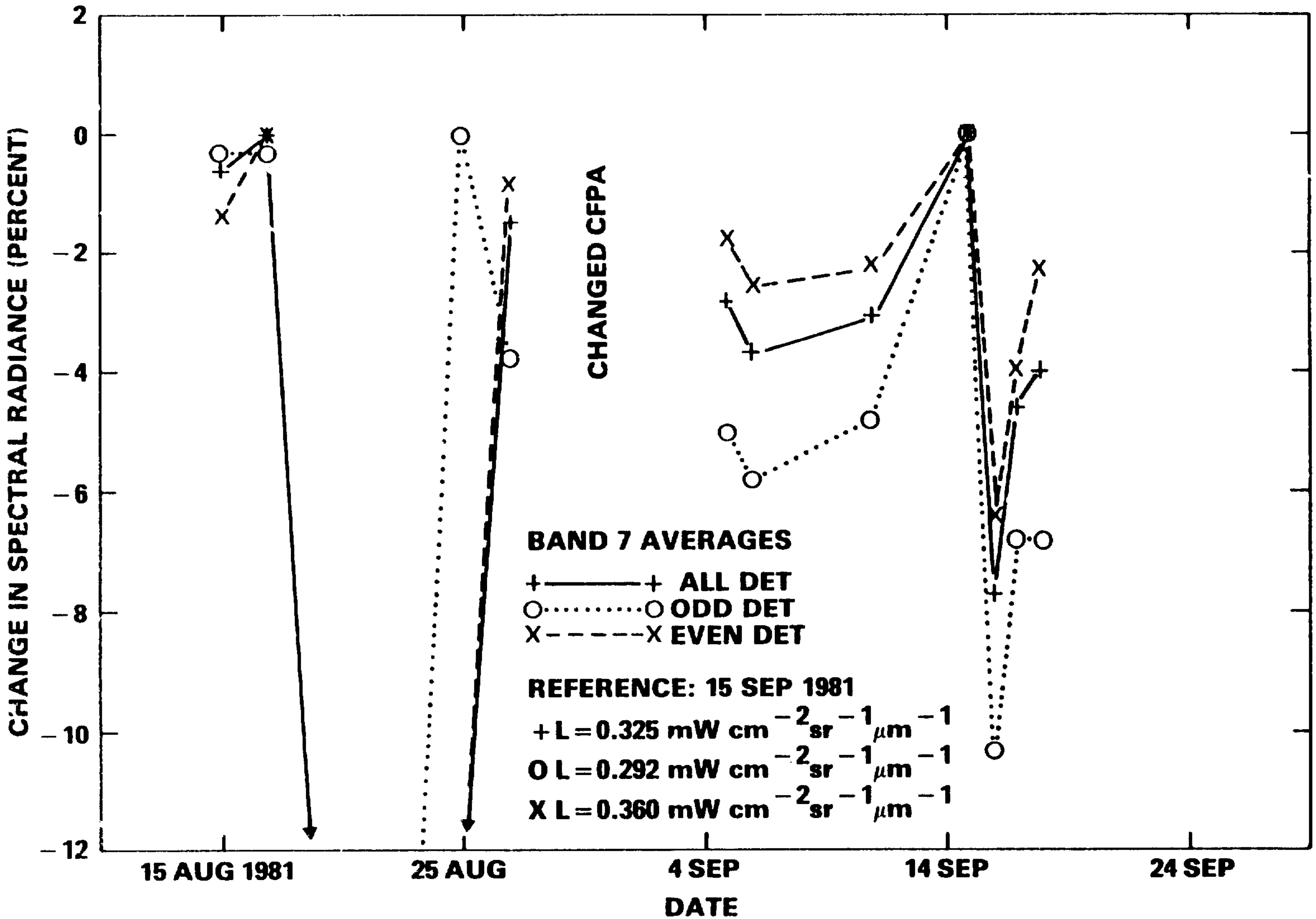
TEST OF DETECTOR AND INTERNAL CALIBRATOR STABILITY



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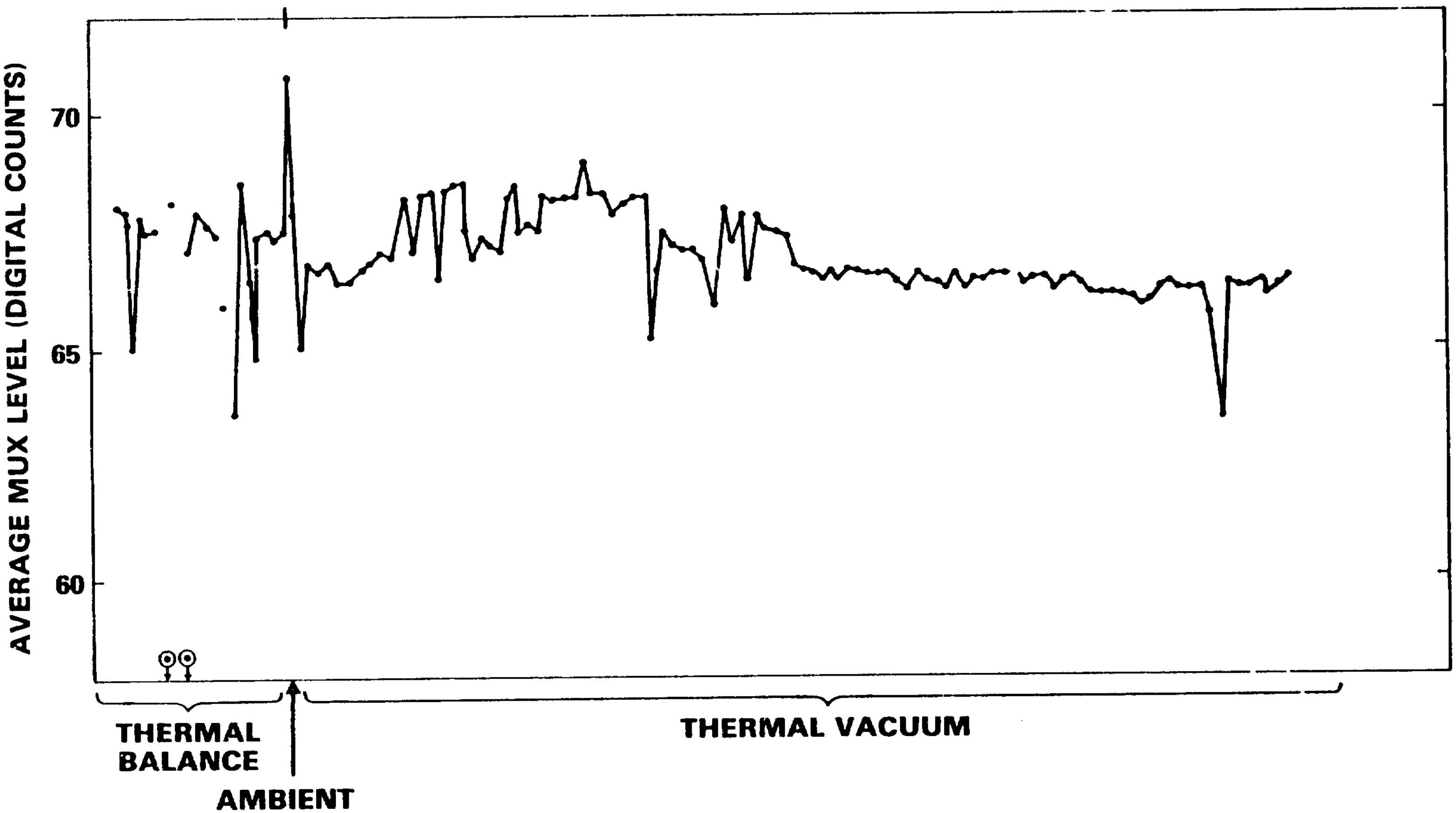
SUMMARY OF VALLEY FORGE FLOODING LAMP TESTS

AVERAGE RADIANCE FOR BAND 1 DETECTOR 1



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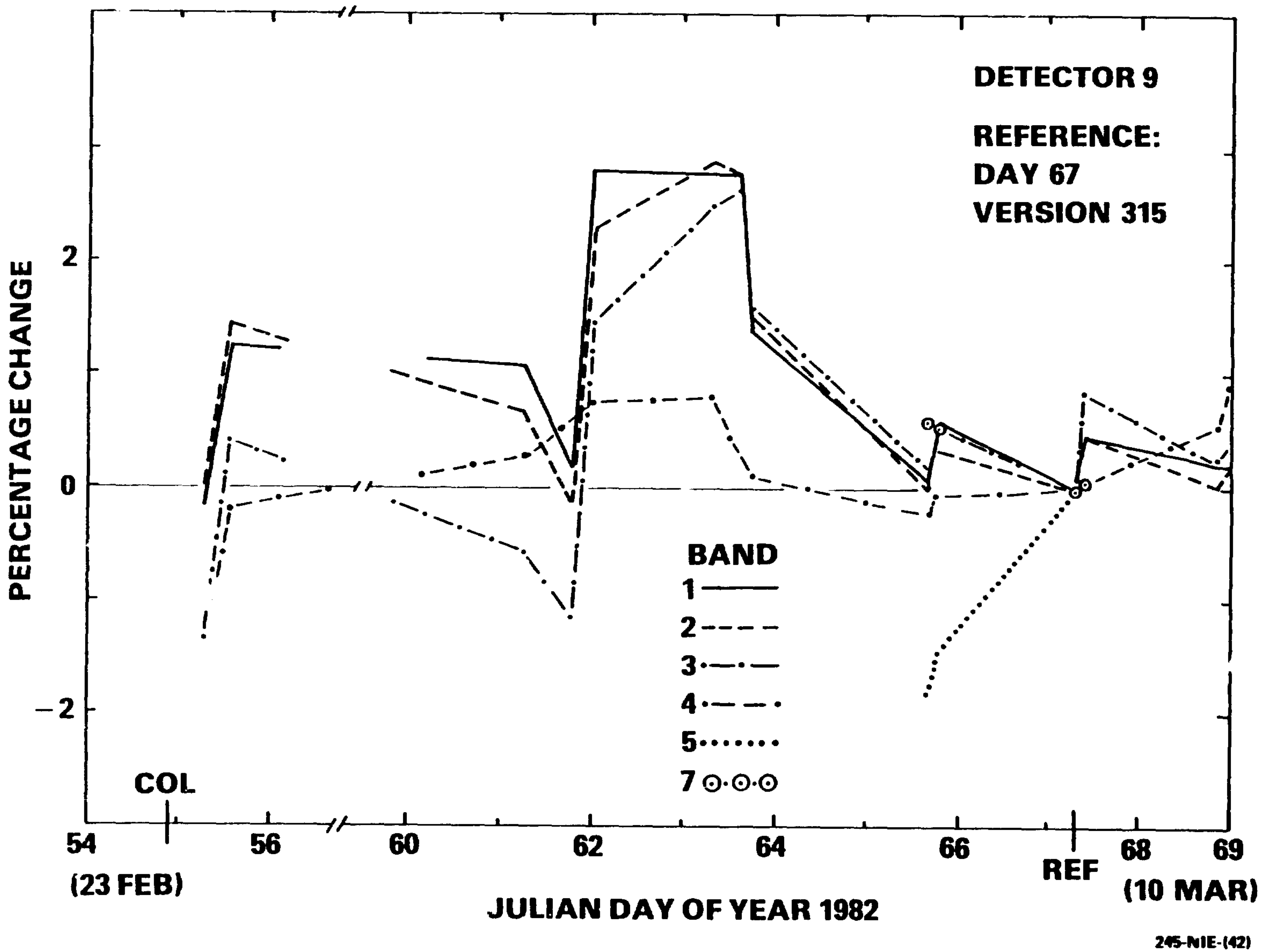
SUMMARY OF VALLEY FORGE THERMAL-VACUUM TEST

TEST OF DETECTOR AND FLOODING LAMP STABILITY



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DEMONSTRATION OF INTERNAL CALIBRATION (IC) SYSTEM

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TM/PF RADIOMETRIC CALIBRATION OF FLOODING LAMP DATA

BAND 3, CHANNEL 9

VERSION FEB-MAR 1982 THERMAL VACUUM	OBSERVED MID SCAN AVERAGE OBS (COUNTS)	DATA FROM IC: GAIN CHANGE ΔM (PPT)	DATA FROM IC: BIAS CHANGE ΔFF (COUNTS)	ADJUSTED* MID SCAN AVERAGE ADJ (COUNTS)
250	114.73	9	.1	115.86
255	114.62	12	.2	116.20
260	113.44	16	.1	115.36
277	111.79	21	.1	114.24
301	112.31	20	.1	114.65
315	111.69	20	.1	114.02
317	112.62	9	.0	113.63
MEAN (COUNTS)	113.03			114.85
STANDARD DEV (COUNTS)	±1.27			±0.97

*$ADJ = OBS * (1 + \frac{\Delta M}{1000}) + \Delta OFF$

RADIOMETRIC CALIBRATION OF TM/PF FLOODING LAMP DATA

CHANNEL 9

BAND	OBSERVED MEAN	ADJUSTED MEAN	STANDARD DEVIATION OBSERVER	STANDARD DEVIATION AFTER ADJ
1	66.08	67.31	.79	.67
2	67.72	67.57	.83	.72
3	115.03	114.85	1.27	.97
4	73.17	75.03	.35	.36

NORMALIZE TO BAND 4

- FIND THE CORRELATIONS BETWEEN BANDS 1, 2, 3, & 4
- ESTIMATE A TRUE BAND 4 VALUE BASED ON AVERAGING OF OBSERVED AND THREE PREDICTED VALUES
- NORMALIZE BANDS 1, 2, & 3 BY CALCULATING THE DIFFERENCE OF THE AVERAGE BAND 4 FOR A PARTICULAR VERSION FROM THE AVERAGE FOR ALL VERSIONS

THE RESULTS ARE:

	TM1	TM2	TM3	TM4	TM5	TM7
TRUE MEAN	66.08	66.72	113.02	73.17	107.54	98.18
σ	.08	.05	.13	.07	1.08	.32
CV(%)	.13	.07	.12	.03	1.00	.33

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TM/PF CALIBRATION TRANSFER

INTERNAL CALIBRATOR CONSISTENCY CHECK*

CALIBRATION PULSE SUM (DIGITAL COUNTS)

(LAMP LEVELS 101-100-001+000)

BAND	1	2	3	4	5	7
TEST 1	-0.090	-0.033	-0.234	-0.881	+0.262	+0.231
TEST 4	+0.376	+0.316	+0.211	-1.044	+0.140	-0.305

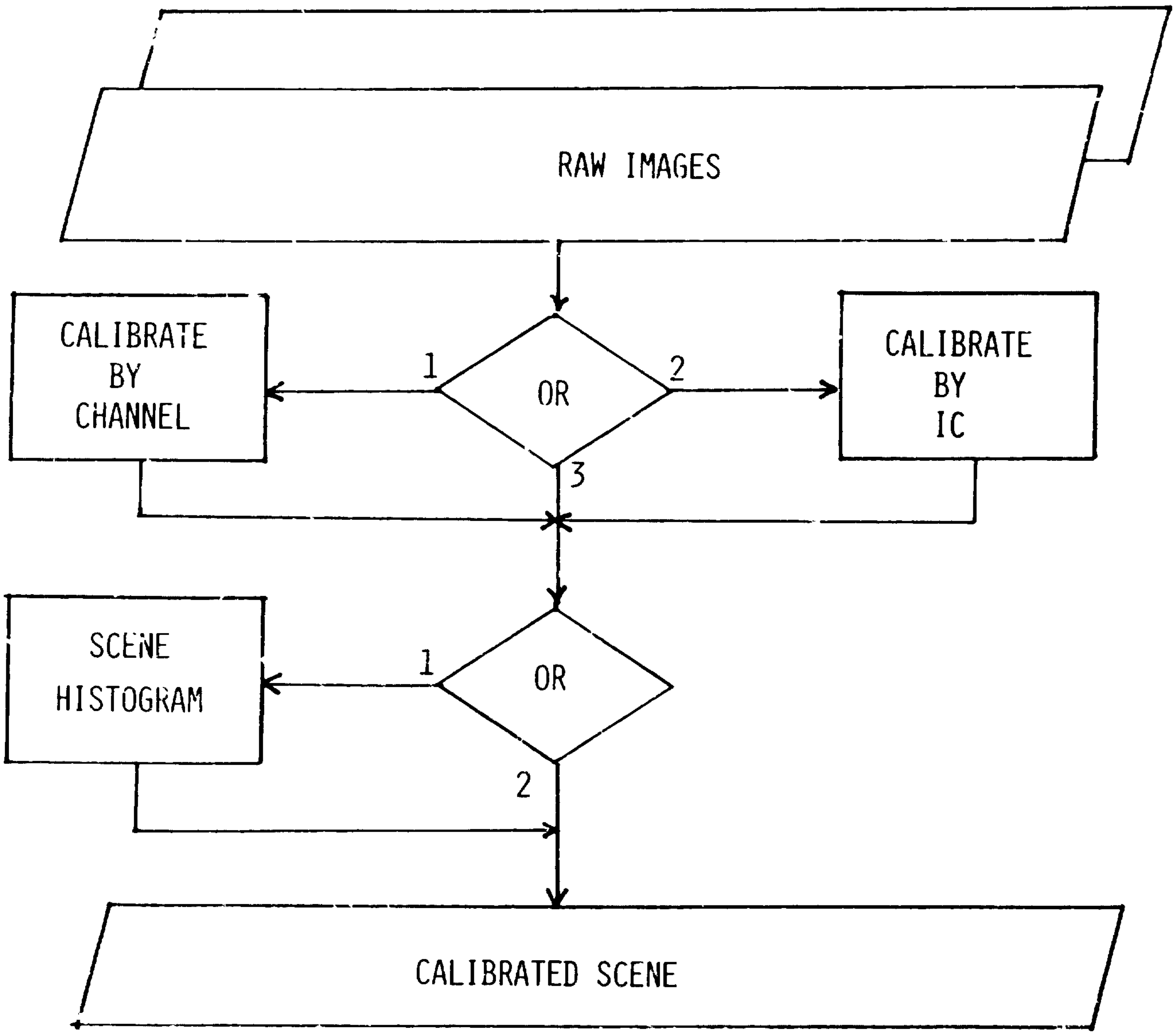
* SPHERE RADIANCE IS ASSUMED TO BE CONSTANT FOR ALL TESTS

DETECTOR 9 IN EACH BAND HAS BEEN USED

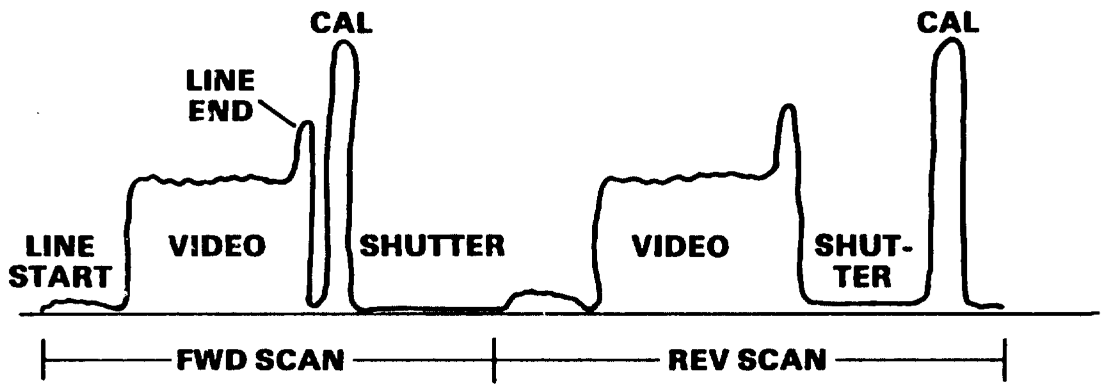
CONCLUSION:

IC CHECKS ARE CONSISTENT FOR ALL BANDS TO WITHIN 1 DIGITAL COUNT

TM RADIOMETRIC GROUND PROCESSING



REPRESENTATION OF TM TIME SEQUENCE



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C-2

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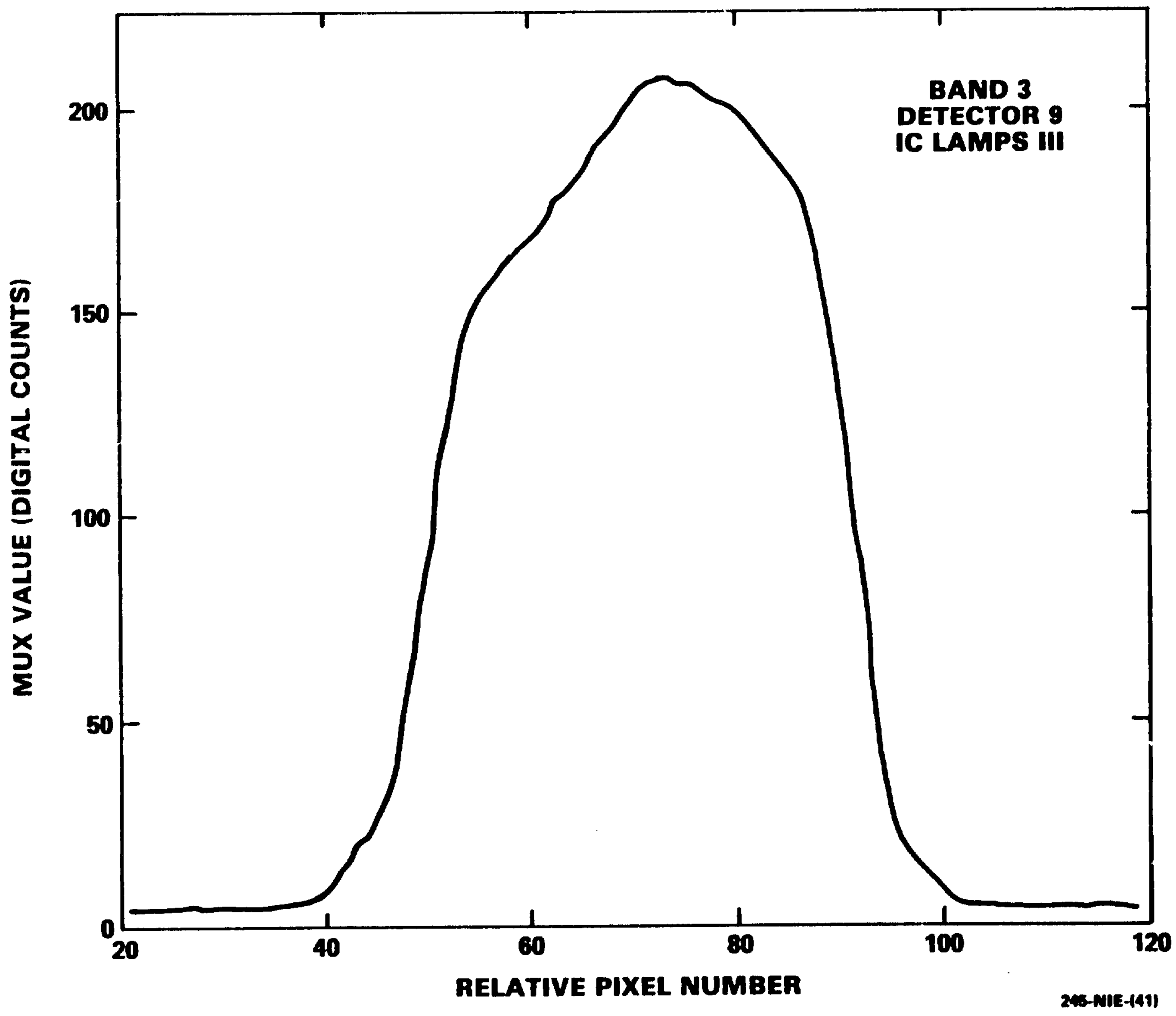
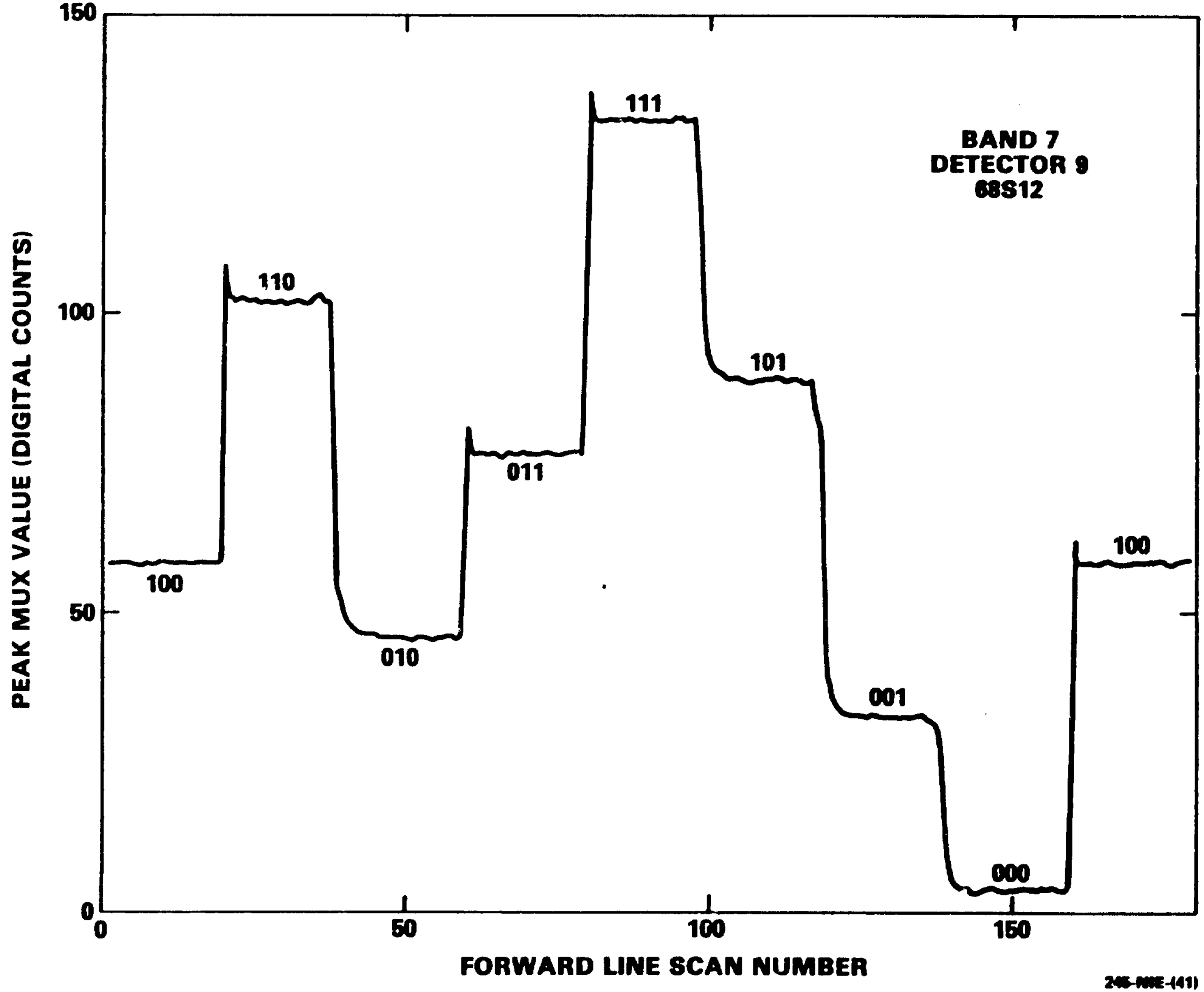
TYPICAL TM/PF CALIBRATION PULSE



TM/PF INTERNAL CALIBRATOR LAMP SEQUENCE SHOWING LAMP OVERSHOOT AND THERMAL RELAXATION



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TM RADIOMETRIC PRE-PROCESSING PROCEDURES (TIPS)

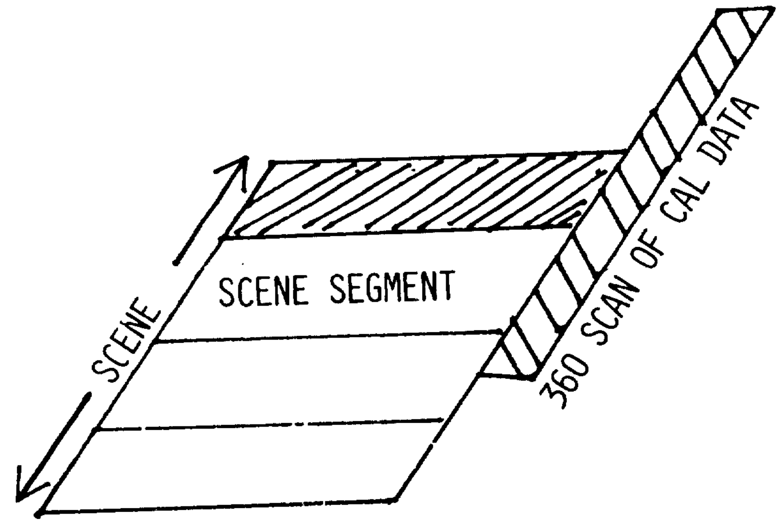
PURPOSE: CONVERT OBSERVED DIGITAL COUNTS INTO COUNTS WHICH ARE PROPORTIONAL TO SCENE RADIANCE BY USING RADIOMETRIC LOOK-UP TABLES (RLUTs)

STEPS:

- CREATE SCENE SEGMENTS
- CALCULATE BAND-NORMALIZED GAIN AND BIAS BY SEGMENT USING INTERNAL CALIBRATOR (IC)
- MODIFY GAIN AND BIAS USING SCENE HISTOGRAMS (OPTIONAL)
- GENERATE RLUT FOR EACH SUBSEGMENT BY BLENDING SEGMENT-LEVEL GAIN AND BIAS

CREATE TM/PF SCENE SEGMENTS

- DIVIDE EACH SCENE INTO 1, 2, 4 OR 8 SEGMENTS (NOMINALLY 4)
- IDENTIFY CENTER LINE OF SEGMENT
- IDENTIFY 360 SCANS OF INTERNAL CALIBRATION DATA AROUND CENTER OF SEGMENT



CALCULATE SEGMENT-LEVEL GAIN AND BIAS FROM INTERNAL CALIBRATION (IC) DATA

- CALCULATE AVERAGE IC PULSE VALUES, $\bar{Q}$, FOR EACH CHANNEL
- CALCULATE INITIAL GAIN (G) AND BIAS (B) FOR EACH CHANNEL
- IDENTIFY COMMON RADIANCE RANGE FOR EACH BAND
- CALCULATE A BAND AVERAGE GAIN ($\bar{G}$) AND BIAS ($\bar{B}$)
- CALCULATE A BAND NORMALIZED GAIN (G') AND BIAS (B') FOR EACH CHANNEL

CALCULATE EIGHT AVERAGE IC VALUES FOR EACH SEGMENT

FOR EACH CHANNEL WITHIN A BAND AND USING AT LEAST 360 SCANS AROUND THE SEGMENT CENTER

- EXTRACT IC PULSE DATA (160 SAMPLES) AND SHUTTER BACKGROUND DATA (50 SAMPLES)
- FIND EDGE INDEX OF PULSE BY ONE OF THREE METHODS
- FIND PULSE CENTER BY AVERAGING EDGES
- SUM N SAMPLES, Q, AROUND PULSE CENTER TO GET SCAN-AVERAGED PULSE VALUE (QSC), N=65 GIVES SMALLER VARIATION THAN N=31
- REJECT TRANSITION PULSES AND OUTLIERS
- IDENTIFY LAMP CONFIGURATION FOR EACH PULSE VALUE
- AVERAGE M VALUES, $\bar{Q}$, FOR EACH LAMP CONFIGURATION

FIND EDGE INDEX OF CALIBRATION PULSE

- THRESHOLD (THRESH, SIMPLEST AND INSENSITIVE TO NOISE)
  FOR BOTH ENDS OF COLLECTION WINDOW, LOCATE FIRST
  BLOCK OF TEN ADJACENT SAMPLES ABOVE A THRESHOLD

- DIFFERENCES OF AVERAGES (DOA, LEAST SENSITIVE TO NOISE)
  TRAVELING AVERAGE OF TWO ADJACENT BLOCKS OF TEN SAMPLES

- HUGHES ALGORITHM (PULSE, MOST SENSITIVE TO NOISE)

CURRENT EDGE LOCATION PARAMETERS

THRESH AND DOA

	REFLECTIVE BANDS	THERMAL BAND
PARAMETER	1-5, 7	6
VALUES IN AVERAGE	65	23
THRESHOLD	20	90
BLOCK SIZE	10	5

PULSE

	REFLECTIVE BANDS	THERMAL BAND
PARAMETER	1-5, 7	6
PERCENT OF PEAK	40 %	80 %

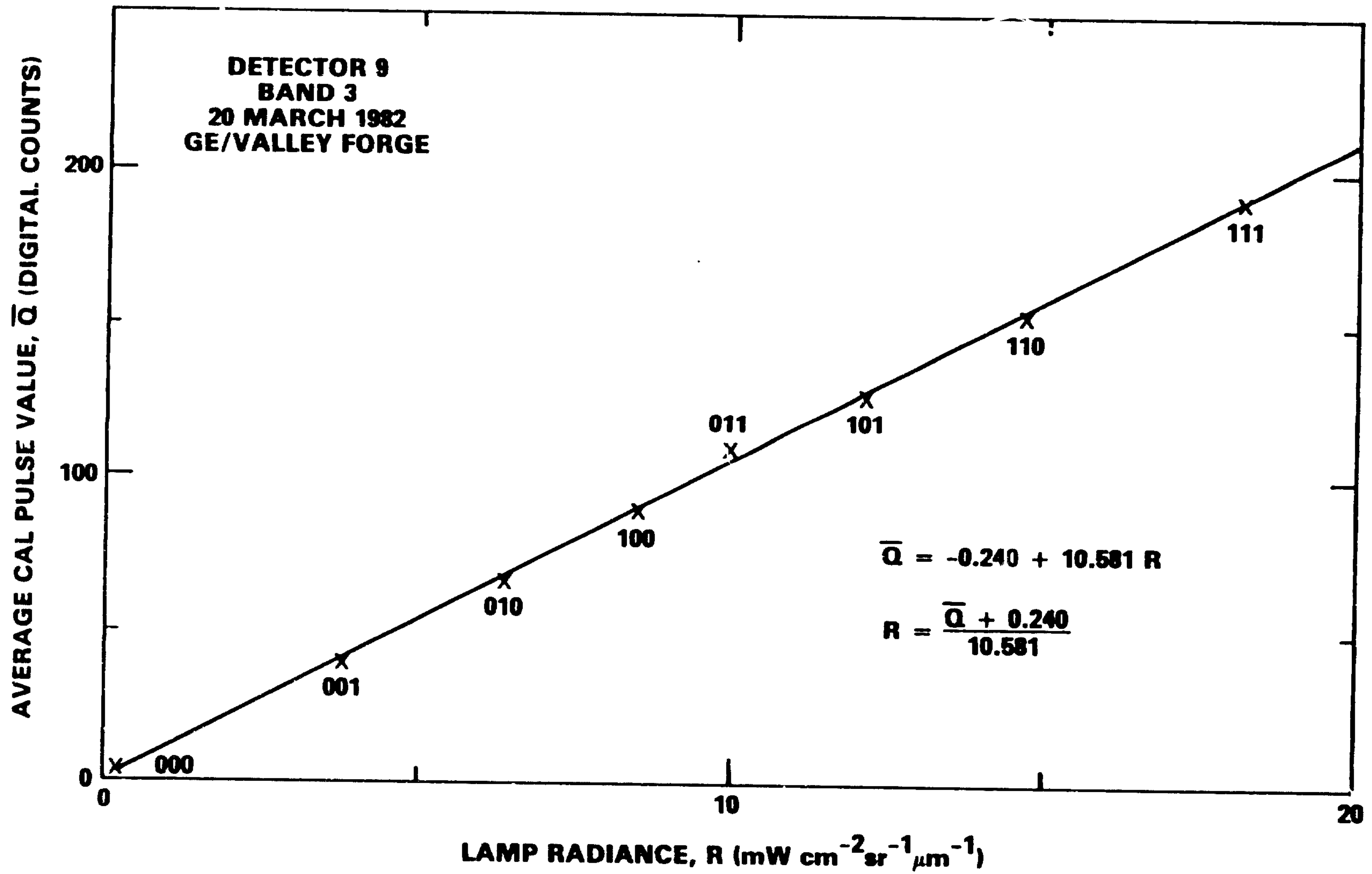
CALCULATE INITIAL GAIN AND BIAS FOR EACH SEGMENT

SIX REFLECTIVE BANDS

SELECT ONE OF THREE MODES:

- A PRIORI GAIN AND BIAS (USE NOMINAL VALUES WITHOUT IC)
- COMPUTED GAIN AND BIAS (USE IC)
- COMPUTED BIAS ONLY (USE NOMINAL GAIN)

ILLUSTRATIVE TM/PF CHANNEL CALIBRATION FOR REFLECTIVE BANDS



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CALCULATE INITIAL GAIN AND BIAS FOR EACH SEGMENT

THERMAL BAND TM 6

FBB = (CB-CS)/(NB-NS)

FBB = BLACK BODY (BB) GAIN FUNCTION

CB = AVERAGE BB PULSE OVER SEGMENT

CS = AVERAGE SHUTTER BACKGROUND VALUE OVER SEGMENT

NB = EFFECTIVE SPECTRAL RADIANCE OF BB
DERIVED FROM OBSERVED BB TEMPERATURE (FROM TELEMETRY)
(NOMINALLY 24°, 30° OR 35°C)

NS = EFFECTIVE SPECTRAL RADIANCE OF SHUTTER
DERIVED FROM OBSERVED SHUTTER TEMPERATURE (FROM TELEMETRY)

THERMAL GAIN = GC = .725 FBB

THERMAL BIAS = KC = (.9 *NS - .19) * FBB

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IDENTIFY COMMON RADIANCE RANGE FOR DETECTORS WITH DIFFERENT SENSITIVITY
(TO AVOID STRIPING)

FOR ALL CHANNELS WITHIN A BAND:

- LOCATE THE CHANNEL WITH THE HIGHEST SENSITIVITY AND CALCULATE ITS RADIANCE FOR A FULL SCALE DIGITAL VALUE OF VMAX

$$RMAX = MIN \left[\frac{VMAX - B}{G} \right]$$

- LOCATE THE CHANNEL WITH THE LOWEST BACKGROUND LEVEL AND CALCULATE ITS APPARENT RADIANCE FOR A ZERO SCALE DIGITAL VALUE OF VMIN

$$RMIN = MAX \left[\frac{VMIN - B}{G} \right]$$

CALCULATE A BAND-AVERAGED GAIN AND BIAS FOR THE SEGMENT

$$\text{BAND-AVERAGED GAIN} = \bar{G} = \frac{VMAX}{(RMAX - RMIN)}$$

$$\text{BAND-AVERAGED BIAS} = \bar{B} = VMIN - \bar{G} * RMIN$$

$$= VMIN - \frac{VMAX * RMIN}{(RMAX - RMIN)}$$

CALCULATE A BAND-NORMALIZED GAIN, BIAS AND RLUT
FOR EACH CHANNEL IN THE SEGMENT

BAND-NORMALIZED GAIN = $G' = G/\bar{G}$

BAND NORMALIZED BIAS = $B' = B - G' * \bar{B}$

CREATE 100 RLUTs OF DIMENSION 256 BY CALCULATING THE INTEGER VALUES OF I' FROM I:

$$(I'-1) = \text{INTEGER}\left[\frac{(I-1) - B'}{G'} + .5\right]$$

WHERE I GOES FROM 1 THROUGH 256

ASSUMPTIONS IN CALIBRATION PROCEDURE WITH IC

- INTERNAL CALIBRATION SYSTEM IS INVARIANT WITH TIME
- INTERNAL CALIBRATION IS MORE CONSTANT THAN DETECTORS
- AVERAGE VALUE IS INDEPENDENT OF TM CONFIGURATION OR ON-TIME
- BACKGROUND LEVEL IS CONSTANT
- RANDOM SHUTTER BACKGROUND
- BETWEEN BAND INFORMATION NOT NEEDED
- HISTORICAL BEHAVIOR NOT NEEDED

USE SCENE HISTOGRAMS TO MODIFY BAND-NORMALIZED GAIN AND BIAS

- COLLECT SCENE HISTOGRAMS OF RAW VIDEO VALUES WITHIN A SEGMENT DURING INITIAL INGEST OF RAW DATA

- CREATE CALIBRATION HISTOGRAMS BY APPLYING RLUTs TO RAW SCENE HISTOGRAMS

HISTOGRAM NORMALIZATION (CONTINUED)

- CREATE A BAND-AVERAGED SCENE HISTOGRAM FROM THE HISTOGRAM OF ALL THE CHANNELS IN THAT BAND
- MODIFY EACH CHANNEL HISTOGRAM, RH, SO THAT IT HAS THE SAME MEAN, MEAN(RH), AND STANDARD DEVIATION, SD(RH), AS THE BAND-AVERAGED HISTOGRAM, $\overline{RH}$, USING THE FORMULA:

$$\overline{RH} = G * RH + B$$

$$\text{AND} \quad G = SD(\overline{RH})/SD(RH)$$

$$B = MEAN(\overline{RH}) - G * MEAN(RH)$$

- CALCULATE A HISTOGRAM-NORMALIZED GAIN, G″, AND BIAS, B″

  $G'' = G'/G$ AND $B'' = B' - G'' * B$

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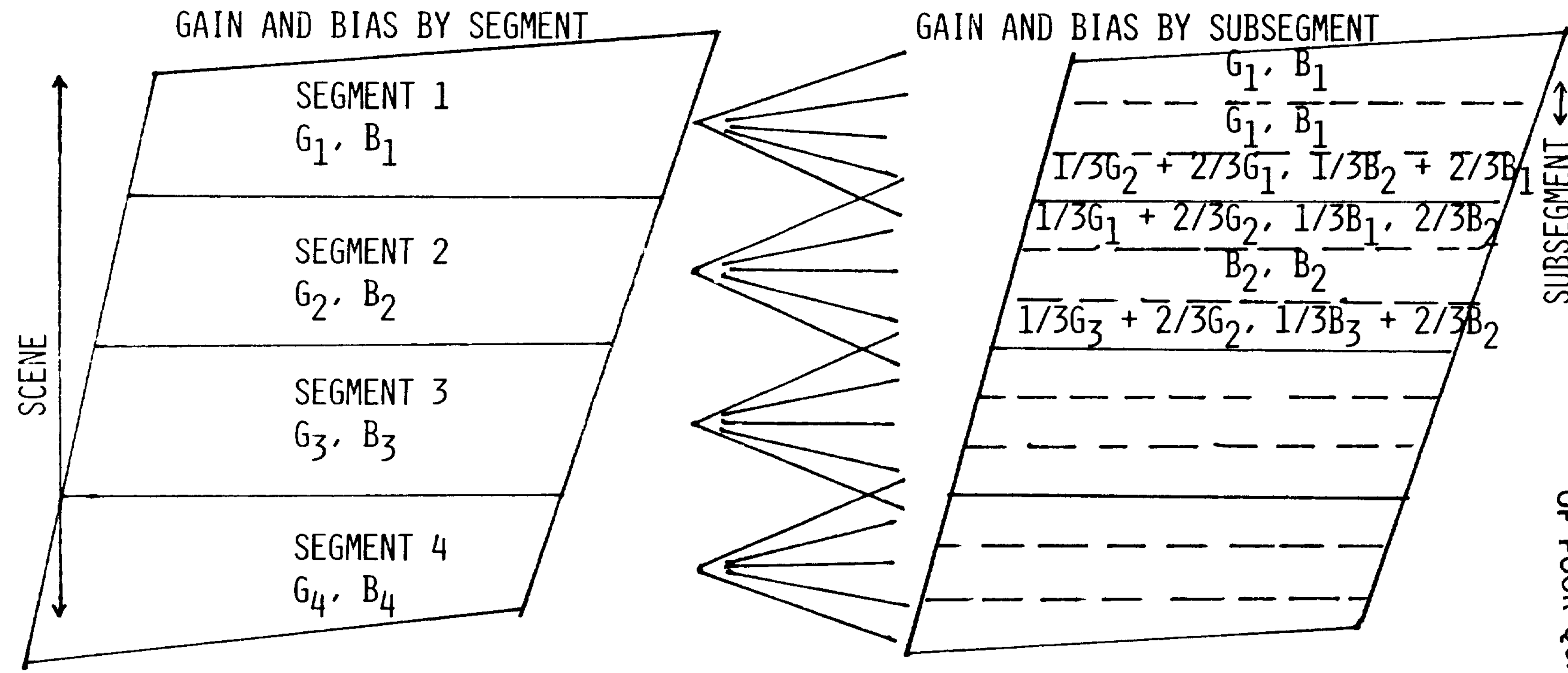
ASSUMPTIONS IN CALIBRATION ADJUSTMENTS WITH SCENE HISTOGRAMS

- STATISTICALLY IDENTICAL SAMPLING FOR EACH CHANNEL
- CHANNEL RESPONSE IS LINEAR
- ROUNDING IN RLUTs NOT SIGNIFICANT

GENERATE THE RLUT FOR EACH SUBSEGMENT
BY BLENDING ADJACENT SEGMENT LEVEL GAINS AND BIASES



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- NOMINAL NUMBER OF SEGMENTS IS 4
- NOMINAL NUMBER OF SUBSEGMENTS IS 3
- GAINS AND BIASES CAN BE EITHER BAND-NORMALIZED FROM IC DATA OR HISTOGRAM-NORMALIZED FROM SCENE DATA
- CREATE RLUT FOR EACH SUBSEGMENT BASED ON INTERPOLATED GAINS AND BIASES

TM Geometric Sensor Performance

Jack Engel

THE GEOMETRIC PROPERTIES OF THE THEMATIC MAPPER

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DISCUSSION TOPICS

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- INSTANTANEOUS FIELD OF VIEW SIZE
- RISE TIME
- DELAY TIME
- MTF (SQUARE WAVE RESPONSE)
- BRIGHT TARGET RECOVERY
- ALTITUDE EFFECTS
- BAND-TO-BAND REGISTRATION
- SCAN PROFILE LINEARITY

5/32

INSTANTANEOUS FIELD OF VIEW SIZE

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SPATIAL COVERAGE
PROTOFLIGHT MODEL

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COOLED FOCAL PLANE

BAND	CHANNEL	LINE SPREAD FUNCTION WIDTH (μrad)		
		TRACK	SCAN	SPECIFIED
5	2	47.5	42.6	≤ 46.35
5	16	46.9	42.5	
7	2	47.8	45.5	
7	16	49.6	44.8	
6	1	172.2	173.0	≤ 174.4
6	2	173.8	170.2	
6	3	177.5	178.3	
6	4	175.3	174.0	

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SPATIAL COVERAGE PROTOFLIGHT MODEL

PRIME FOCAL PLANE

BAND	CHANNEL	LINE SPREAD FUNCTION WIDTH (μrad) TRACK	SCAN	SPECIFIED
1	2	44.4	44.0	≤43.2
1	16	43.4	42.3	
2	1	44.8	44.9	
2	15	---	---	
3	2	45.5	45.1	
3	16	43.9	44.9	
4	2	44.0	44.1	
4	16	43.1	44.5	

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STEP RESPONSE CHARACTERISTICS

STEP RESPONSE
BANDS 1 TO 5, & PROTOFLIGHT MODEL

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PARAMETER	SPECIFICATION	PERFORMANCE
OVERSHOOT	$\leq$10%	$\leq$10% 3.5% TYP, BANDS 1-4 8.0% TYP, BANDS 5,7
SETTLING TIMES	$\leq$1.5% ERROR AFTER 30 μSEC	$\leq$1.5% AFTER $\boxed{\text{35 μSEC}}$ EXCEPT BAND 2 CHAN 6 = 2.1% BAND 3 CHAN 2 = 1.8%
	$\leq$1.0% ERROR AFTER 60 μSEC	$\leq$1.0% EXCEPT BAND 2 CHAN 6 = 2.1% $\leq$ 1% IN 100 μs CHAN 8 = 1.1% $\leq$ 1% IN 100 μs BAND 3 CHAN 2 = 1.8% CHAN 8 = 1.1% CHAN 14 = 1.4%
RISETIME	$\leq$20 μSEC	$\leq$17 μSEC
DROOP	$\leq$0.5%	NO DATA

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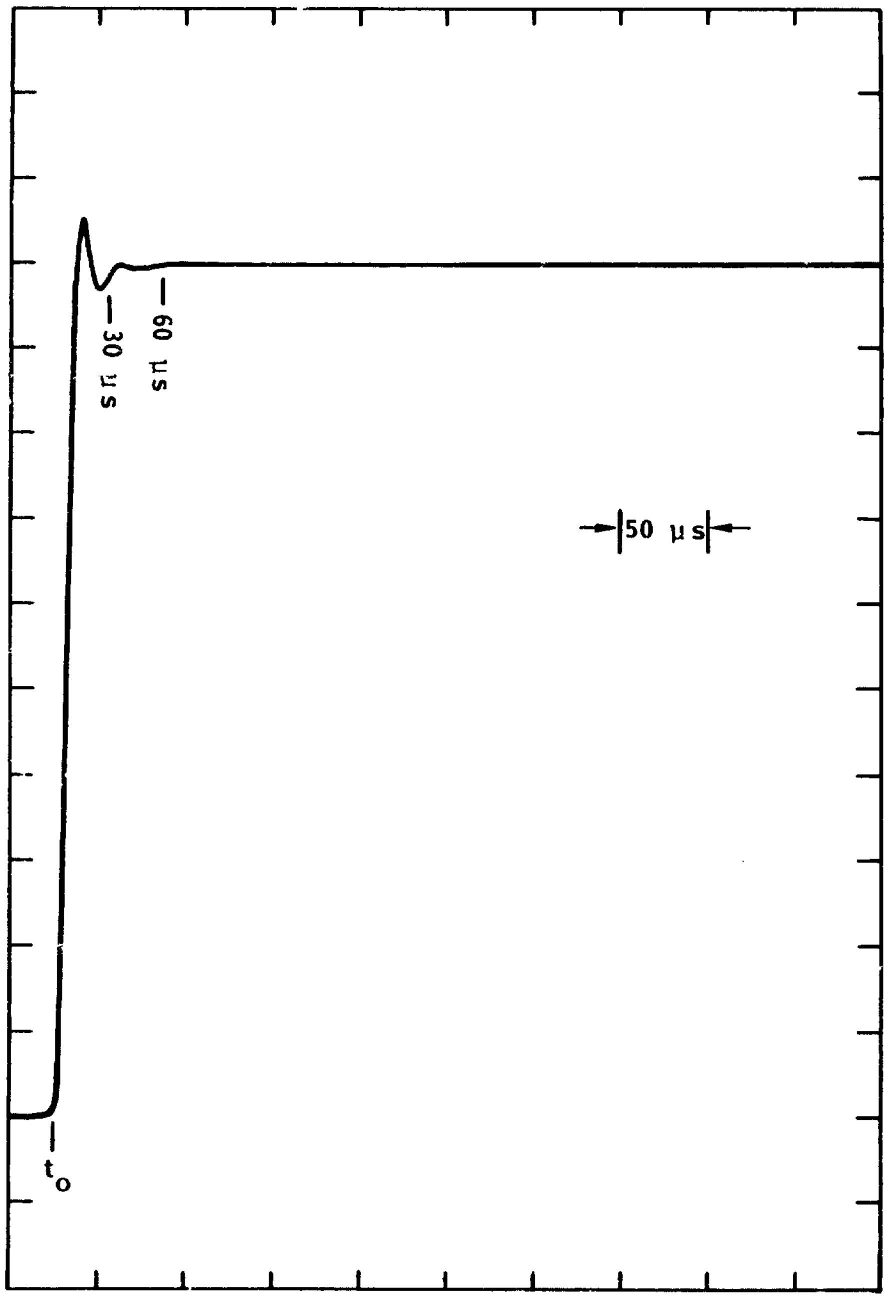

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TYPICAL RESPONSE TO A STEP OF RADIANCE (BANDS 1-4) (BAND 3 CHANNEL 7)

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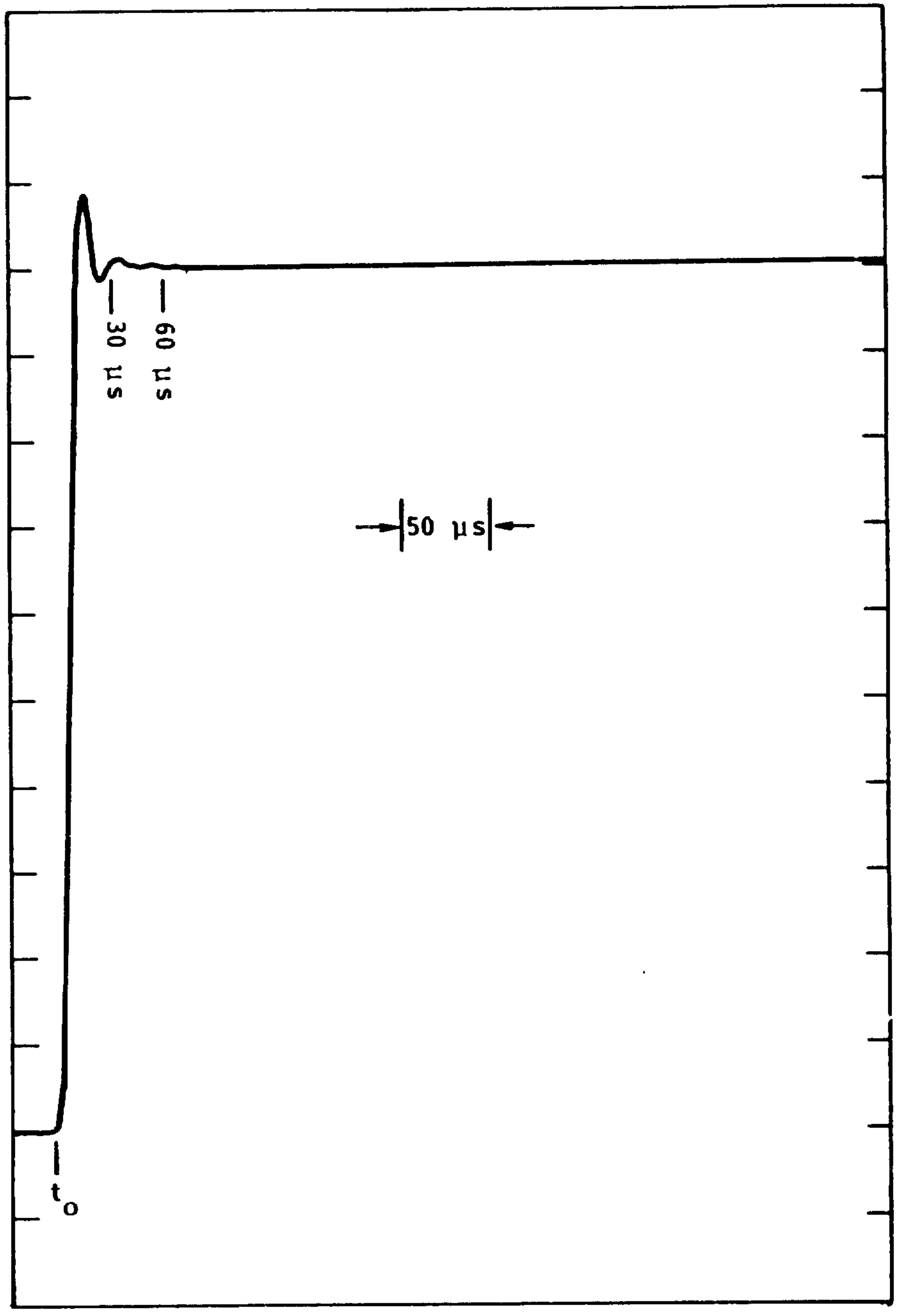

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TYPICAL RESPONSE TO A STEP OF RADIANCE BANDS 5 & 7 (BAND 5 CHANNEL 5)

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STEP RESPONSE BAND 6
PROTOFLIGHT MODEL

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PARAMETER	SPECIFICATION	PERFORMANCE
OVERSHOOT	$\leq$10%	$\leq$3.8%
SETTLING TIMES	$\leq$1.5% ERROR AFTER 120 μSEC	$\leq$1.5% ERROR AFTER 35 μSEC
	$\leq$1.0% ERROR AFTER 240 μSEC	$\leq$1.0% ERROR AFTER 65 μSEC
RISETIME	$\leq$80 μSEC	$\leq$70 μSEC
DROOP	$\leq$0.5%	NO DATA

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RESPONSE DELAY

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TYPICAL RESPONSE DELAY BANDS 1-4

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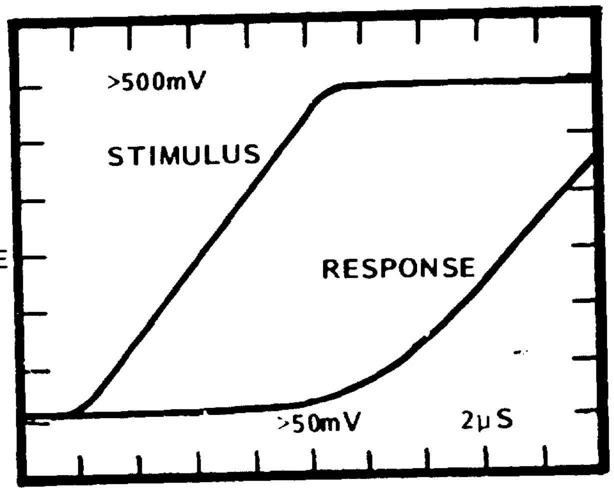
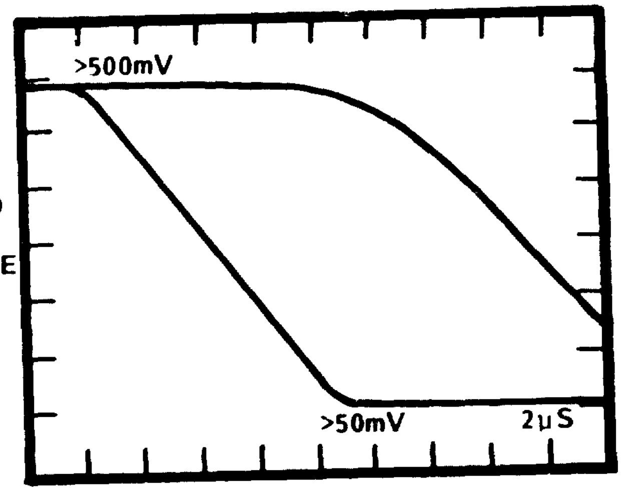
BAND 3
CHANNEL 9

DELAY TIME
11.6 µsec



BAND 3
CHANNEL 9

DELAY TIME
11.4 µsec



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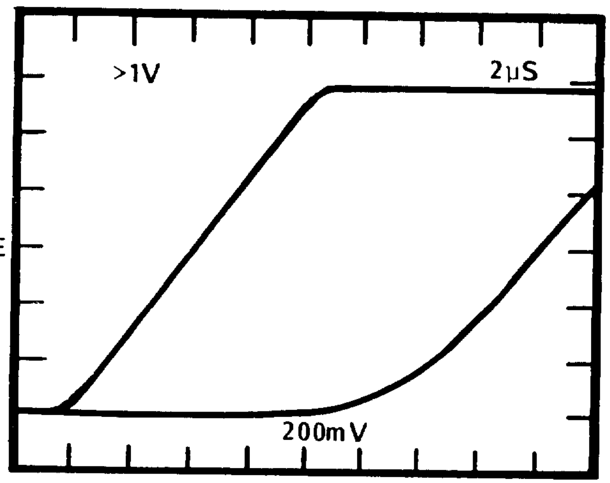
TYPICAL RESPONSE DELAY BANDS 5 & 7

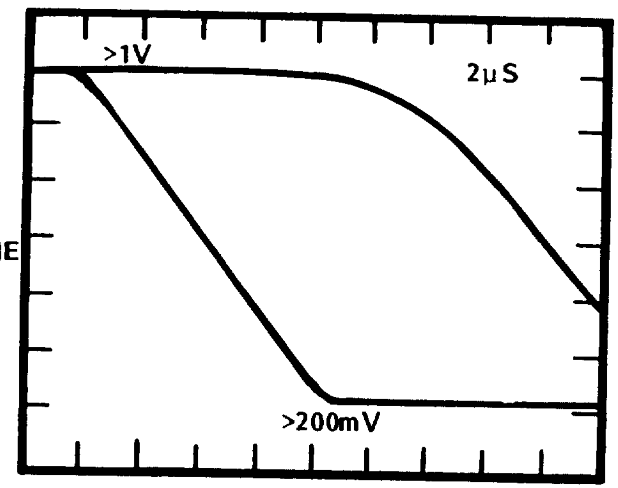
BAND 5
CHANNEL 5

DELAY TIME
11.6 μsec



BAND 5
CHANEL 5

DELAY TIME
12.2 μsec



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DYNAMIC FORWARD SCAN CHANNEL-TO-CHANNEL OFFSETS (REFERRED TO B4D9) IFOV'S

CHANNEL \ BAND	1	2	3	4	7	5
1	+0.08	+0.09	+0.02	-0.03	+0.11	+0.17
2	+0.02	*	-0.02	-0.07	-0.02	+0.02
3	+0.04	+0.05	0.00	-0.04	+0.08	*
4	+0.01	*	-0.03	-0.03	-0.03	0.00
5	+0.03	+0.08	+0.02	-0.04	+0.09	+0.09
6	+0.02	+0.01	+0.03	-0.05	-0.02	+0.08
7	+0.04	+0.05	+0.02	-0.04	*	+0.02
8	-0.02	-0.03	+0.03	-0.02	0.00	+0.15
9	+0.02	+0.06	-0.06	REF	+0.05	+0.09
10	0.00	-0.01	-0.03	-0.04	-0.03	+0.02
11	0.00	+0.04	-0.02	-0.03	+0.08	+0.10
12	0.00	+0.01	+0.02	-0.04	-0.08	0.00
13	+0.05	+0.09	+0.01	+0.02	+0.06	+0.09
14	-0.01	+0.03	+0.04	+0.01	-0.09	+0.05
15	+0.02	+0.09	+0.05	-0.01	+0.09	+0.04
16	+0.03	+0.04	+0.06	+0.01	-0.11	+0.03

* DETECTOR NOT FUNCTIONAL

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CHANNEL \ BAND	1	2	3	4	7	5
1	+0.15	-0.01	+0.03	-0.02	-0.15	-0.08
2	+0.09	•	+0.01	-0.03	0.00	+0.05
3	+0.08	-0.04	-0.01	-0.03	-0.13	•
4	+0.09	•	-0.01	-0.01	-0.02	+0.02
5	+0.06	-0.01	+0.01	-0.04	-0.08	-0.07
6	+0.08	-0.05	+0.04	-0.03	-0.04	+0.11
7	••	-0.06	0.00	-0.04	•	-0.11
8	+0.07	-0.08	+0.04	0.00	+0.01	+0.20
9	+0.03	-0.04	-0.07	REF	-0.10	-0.02
10	+0.05	-0.07	-0.02	-0.02	-0.01	+0.09
11	+0.01	-0.05	-0.03	-0.03	-0.05	+0.02
12	+0.07	-0.06	+0.04	-0.02	-0.04	+0.10
13	+0.07	-0.05	-0.01	+0.02	-0.07	+0.02
14	+0.06	-0.04	+0.04	+0.02	0.00	+0.17
15	+0.03	-0.02	+0.02	-0.01	-0.05	-0.02
16	+0.09	-0.04	+0.07	+0.03	+0.03	+0.21

• DETECTOR NOT FUNCTIONAL

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DYNAMIC REVERSE SCAN CHANNEL-TO-CHANNEL OFFSETS (REFERRED TO B4D9) IFOV'S

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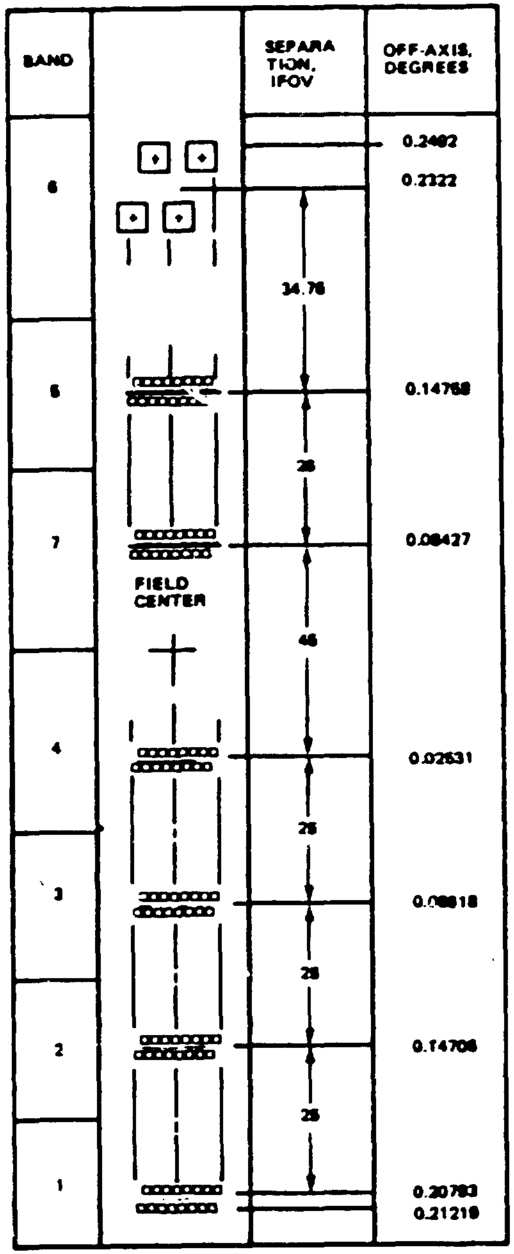

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NOMINAL BAND TO BAND SPACING

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SQUARE WAVE MODULATION

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SQUARE WAVE MODULATION WAS MEASURED USING TWO TECHNIQUES

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- PHASED KNIFE EDGE
  - THE THEMATIC MAPPER SCANS 10 KNIFE EDGES EACH OF WHICH IS SPACED BY 16.1 IFOVs FROM THE PRECEDING EDGE
  - AN EDGE RESPONSE IS CONSTRUCTED FROM THE 10 SAMPLES AND THE SWR IS GENERATED BY PASSING COMPUTER GENERATED BARS OF VARYING SPATIAL EXTENT THROUGH THE RESPONSE EDGE AND COMPUTING THE MAGNITUDE OF THE MODULATION
- SQUARE BAR PATTERNS OF VARYING SPATIAL EXTENT
  - THE THEMATIC MAPPER SCANS BARS OF 34M AND 500M EXTENT
  - THE RESPONSES ARE RATIOED TO EVALUATE THE 34M SWR

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PHASED KNIFE EDGE AND SQUARE BAR PATTERNS

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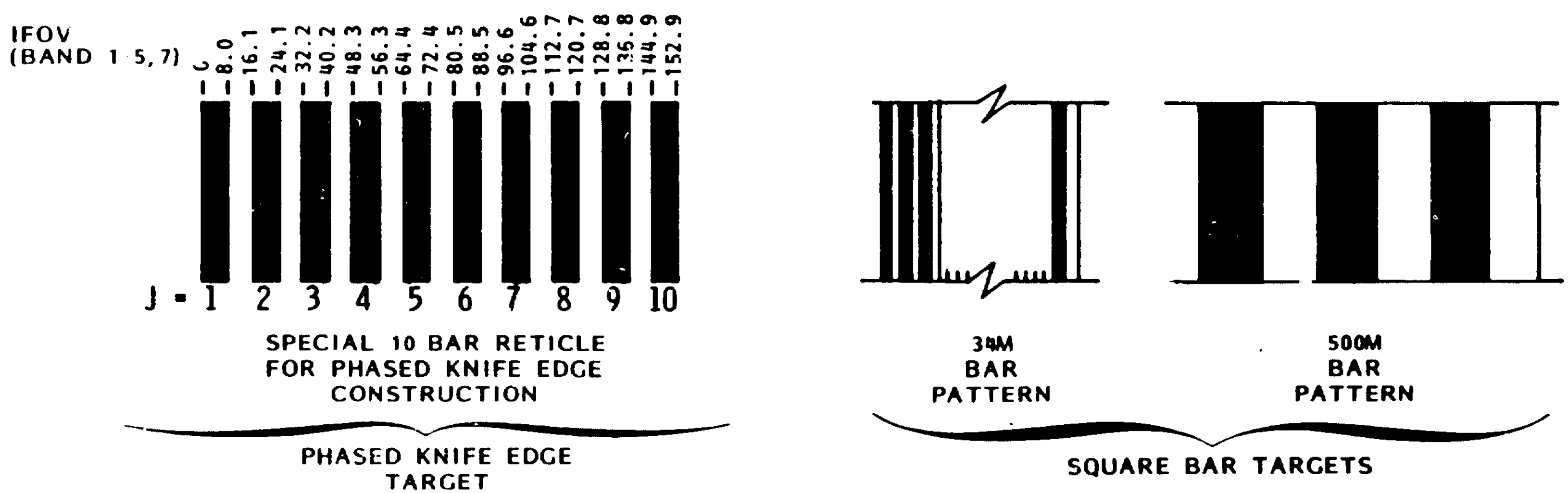

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MEASURED PROTOFLIGHT SQUARE WAVE RESPONSE (SWR) (BAND AVERAGE)

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BAND	30 METER BAR		45 METER BAR		60 METER BAR		500 METER BAR	
	SWR	σ	SWR	σ	SWR	σ	SWR	σ
1	0.46	0.01	0.76	0.03	0.94	0.02	1.0	0.0
2	0.44	0.02	0.72	0.04	0.96	0.03	1.0	0.0
3	0.41	0.01	0.72	0.02	0.91	0.02	1.0	0.0
4	0.43	0.01	0.76	0.03	0.95	0.03	1.0	0.0
5	0.42	0.02	0.78	0.03	0.89	0.03	1.0	0.0
7	0.44	0.02	0.76	0.02	0.92	0.02	1.0	0.0
SPEC	0.35		0.70		0.85		1.0	
BAND	120 METER BAR		180 METER BAR		240 METER BAR		2000 METER BAR	
	SWR	σ	SWR	σ	SWR	σ	SWR	σ
6	0.44	0.04	0.78	0.01	0.94	0.00	1.0	0.0
SPEC	0.35		0.70		0.85		1.0	

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TM PROTOFLIGHT/THERMAL VAC 9/15/81 COLLECTS

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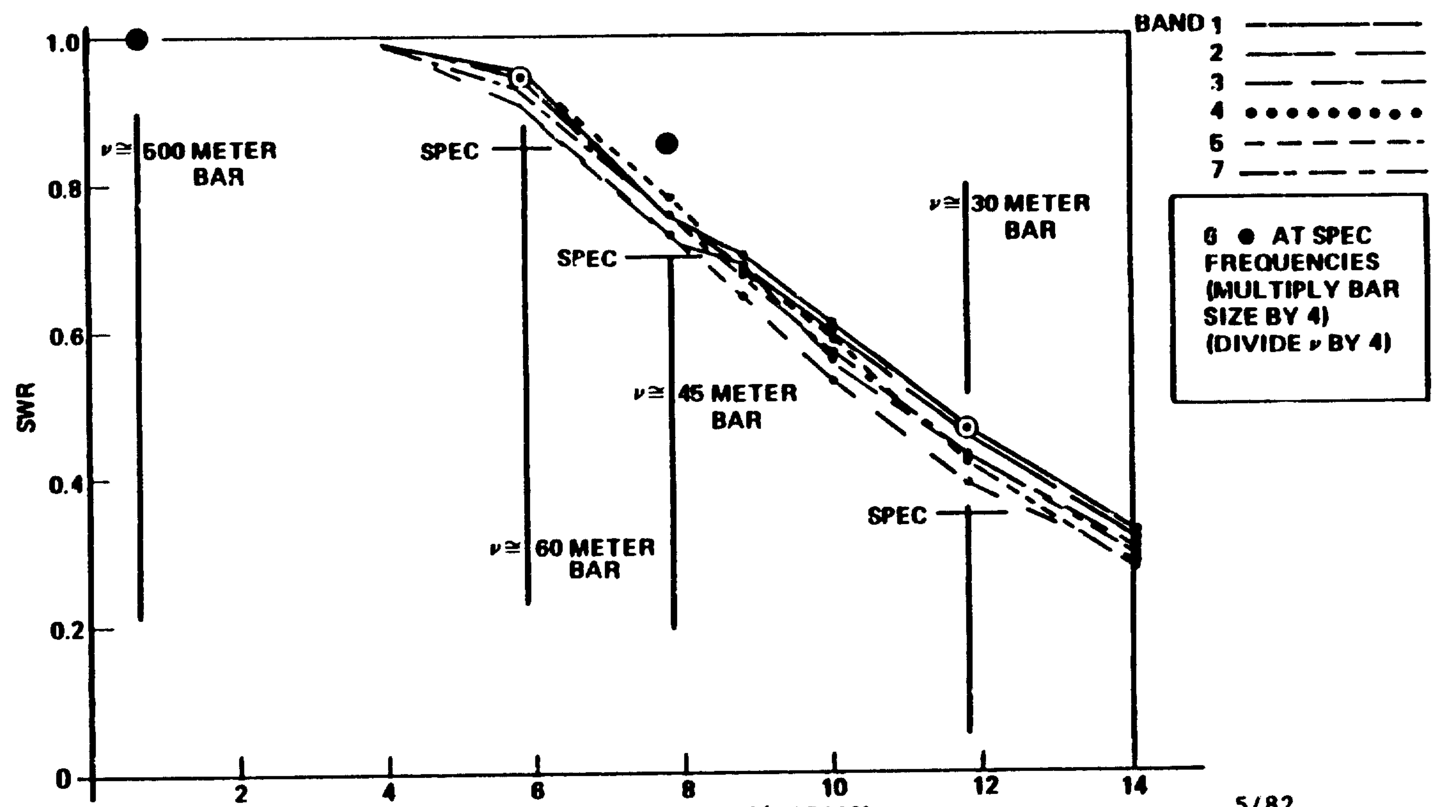

SPATIAL FREQUENCY – K CYCLES/RADIAN, ν

TYPICAL SWR/BAND VS SPATIAL FREQUENCY
CHANNEL 9 IN BANDS 1 TO 5, 7 CHANNEL 4 IN BAND 6

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BRIGHT TARGET RECOVERY

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BRIGHT TARGET RECOVERY

TABLE SHOWS IN BAND RADIANCES FOR WHICH A RECOVERY TIME OF LESS THAN 4 IFOV DWELL TIMES IS INSURED. RECOVERY FROM LARGER SIGNALS TAKES 10 IFOV DWELL TIMES (TYPICAL).

WORST CASE NUMBERS ARE BASED ON A THEORETICAL ANALYSIS OF THE PREAMPLIFIER ELECTRONICS.

BAND	IN BAND BRIGHT TARGET RADIANCE ($MW/CM^2/STER$)		
	SPEC	TYPICAL AT 17°C	WORST CASE AT 12°C
1	2.0	7.9*	6.0
2	4.5	6.2	4.7
3	2.9	4.6	3.5
4	5.0	5.1*	3.5 *
5	1.3	14.2	10.7
6	330 K	—	500°K
7	0.8	8.5	6.4

*BASED ON PROTOFLIGHT PREAMPLIFIER GAIN

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ALTITUDE EFFECTS

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GROUND TRACE OVERLAP/UNDERLAP AT 40° N DESIGN POINT

μrad

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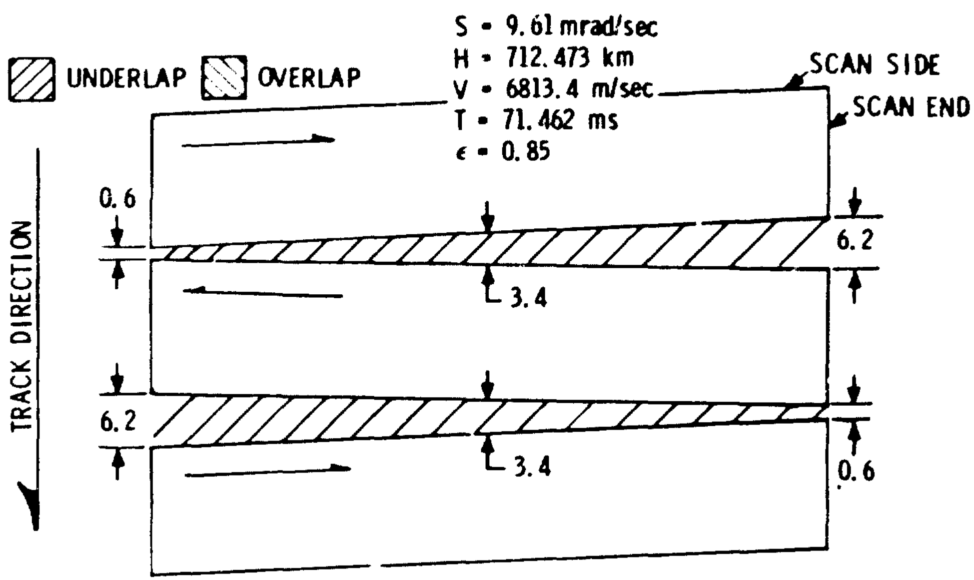
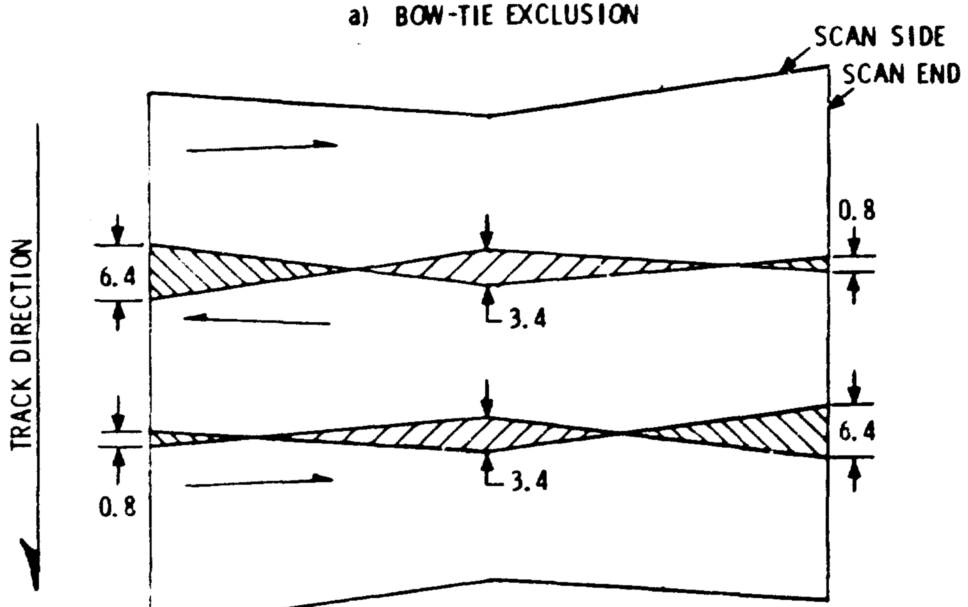


a) BOW-TIE EXCLUSION



b) BOW-TIE INCLUSION

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OVERLAP/UNDERLAP (μRAD)

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SOURCE	PROTOFLIGHT UNDER	OVER	RANDOM*
NOMINAL ORBIT AND SCAN PARAMETERS**	3.4	-3.4	
BOW TIE EFFECT	0.0	6.5	
SMA			
SM CROSS AXIS MOTION	2.0	2.0	1.0†
SM PERIOD VARIATION	2.6	1.3	0.0
VIBRATION			0.5
RADIOMETER			
NON-IDEAL SLC SCAN	2.0	2.0†	0.2
EFL DEVIATION			
TELESCOPE	-1.0	1.0	
RELAY OPTICS	4.3††	4.3††	
DETECTOR IFOV SIZE	-5.4††	+5.4††	
VIBRATION	-1.7†††	+1.7†††	1.4
TOTAL PFPA	7.3	11.1	1.8
TOTAL CFPA	7.9	10.5	
SPECIFICATION		8.5	
EFFECT OF ORBITAL ALTITUDE VARIATIONS BETWEEN 45°N AND 45°S LATITUDES	22.0	15.7	

*1 SIGMA
**ALTITUDE = 712.5KM
VELOCITY = 6821 KM/SEC
SCAN PERIOD = 142.925 MSEC

† OVER FULL TEMPERATURE RANGE
†† AFFECTS COOLED FOCAL PLANE ONLY
††† AFFECTS PRIME FOCAL PLANE ONLY

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BAND-TO-BAND REGISTRATION

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MAP OF TM FOCAL PLANE REGISTRATION BANDS (1 TO 5, AND 7) AS PROJECTED ON GROUND

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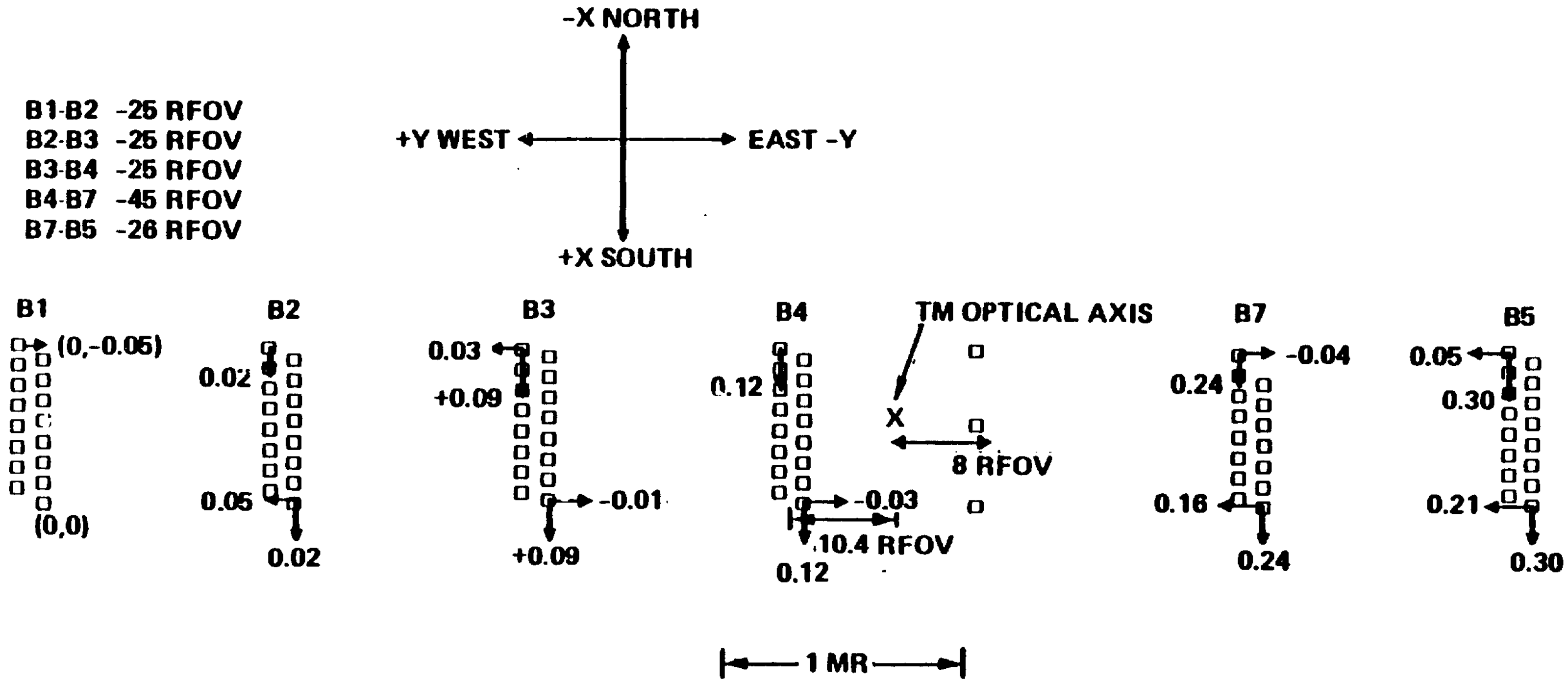

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FORWARD SCAN (UNITS ARE RFOV)
Data taken 18 September 1981

RT	B2-B1	B3-B1	B4-B1	B7-B1	B5-B1
30	24.99	50.02	75.05	120.00	146.04
29	24.96	49.99	75.03	119.93	145.95
28	24.98	50.01	75.04	119.93	145.95
27	24.99	50.03	75.05	119.93	145.98
26	24.97	50.02	75.05	119.95	145.96
25	24.96	50.00	75.03	119.93	145.95
24	24.95	50.00	75.02	119.91	145.91
23	24.95	49.99	75.01	119.89	145.88
22	24.94	50.00	75.02	119.91	145.91
21	24.96	50.03	75.06	119.94	145.95
20	24.97	50.04	75.08	119.96	145.98
19	24.96	50.02	75.04	119.93	145.95
18	24.95	50.02	75.05	119.92	145.94
17	24.95	50.01	75.04	119.90	145.91
16	24.96	50.02	75.04	119.93	145.93
15	24.97	50.03	75.05	119.94	145.96
14	24.96	50.03	75.06	119.94	145.95
13	24.96	50.03	75.05	119.93	145.95
12	24.95	50.02	75.03	119.89	145.91
11	24.96	50.02	75.04	119.89	145.90
10	24.96	50.02	75.04	119.89	145.92
9	24.96	50.01	75.04	119.85	145.88
8	24.96	50.01	75.03	119.85	145.88
7	24.97	50.01	75.03	119.82	145.85
6	24.96	50.01	75.02	119.82	145.82
5	24.97	50.04	75.05	119.84	145.86
4	24.97	50.04	75.05	119.84	145.88
3	24.98	50.06	75.08	119.88	145.90
2	24.99	50.07	75.10	119.85	145.93
NOMINAL	25.00	50.00	75.00	120.00	146.00
AVERAGE	24.96	50.02	75.04	119.90	145.92
STD. DEV.	0.01	0.02	0.02	0.04	0.05

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BAND TO BAND REGISTRATION - ALONG SCAN

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REVERSE SCAN (UNITS ARE RFOV)
Data taken 18 September 1981

RT	B2-B1	B3-B1	B4-B1	B7-B1	B5-B1
2	-24.96	-50.03	-75.10	-119.99	-146.11
3	-24.88	-49.95	-74.98	-119.86	-145.93
4	-24.91	-49.98	-74.95	-119.64	-145.91
5	-24.94	-49.98	-74.95	-119.63	-145.91
6	-24.89	-49.93	-74.92	-119.80	-145.88
7	-24.87	-49.94	-74.93	-119.79	-145.87
8	-24.89	-49.93	-74.92	-119.77	-145.86
9	-24.88	-49.93	-74.92	-119.79	-145.86
10	-24.89	-49.92	-74.90	-119.79	-145.85
11	-24.90	-49.94	-74.91	-119.80	-145.87
12	-24.92	-49.96	-74.95	-119.86	-145.93
13	-24.90	-49.94	-74.94	-119.85	-145.92
14	-24.89	-.9.93	-74.92	-119.83	-145.89
15	-24.91	-49.95	-74.94	-119.86	-145.91
16	-24.89	-49.91	-74.90	-119.80	-145.87
17	-24.89	-49.92	-74.92	-119.83	-145.90
18	-24.91	-49.94	-74.92	-119.83	-145.90
19	-24.91	-49.93	-74.92	-119.83	-145.89
20	-24.89	-49.92	-74.90	-119.81	-145.86
21	-24.83	-49.91	-74.89	-119.79	-145.84
22	-24.69	-49.92	-74.90	-119.83	-145.88
23	-24.90	-49.92	-74.90	-119.82	-145.87
24	-24.85	-49.86	-74.85	-119.76	-145.81
25	-24.89	-49.92	-74.88	-119.81	-145.83
26	-24.89	-49.92	-74.88	-119.77	-145.81
27	-24.91	-49.92	-74.89	-119.78	-145.82
28	-24.87	-49.86	-74.86	-119.77	-145.80
29					
30	-24.91	-49.92	-74.91	-119.87	-145.90
NOMINAL	-25.00	-50.00	-75.00	-120.00	-146.00
AVERAGE	-24.69	-49.93	-74.92	-119.81	-145.88
STD. DEV.	0.02	0.03	0.04	0.06	0.06

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BAND TO BAND REGISTRATION - ALONG SCAN

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BAND TO BAND REGISTRATION - CROSS SCAN

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FORWARD SCAN (UNITS ARE RFOV)
Data taken 18 September 1981

RT	B2-B1	B3-B1	B4-B1	B7-B1	B5-B1
30	-0.01	-0.09	-0.13	-0.30	-0.22
29	-0.01	-0.06	-0.08	-0.14	-0.23
28	0.00	-0.07	-0.10	-0.16	-0.20
27	-0.01	-0.07	-0.09	-0.15	-0.19
26	-0.02	-0.08	-0.10	-0.15	-0.20
25	-0.02	-0.08	-0.11	-0.16	-0.23
24	-0.03	-0.10	-0.13	-0.16	-0.23
23	-0.01	-0.08	-0.10	-0.15	-0.22
22	-0.03	-0.10	-0.12	-0.20	-0.23
21	-0.01	-0.06	-0.10	-0.18	-0.24
20	-0.02	-0.08	-0.10	-0.14	-0.22
19	-0.03	-0.08	-0.11	-0.18	-0.25
18	0.00	-0.07	-0.10	-0.17	-0.20
17	-0.01	-0.08	-0.12	-0.22	-0.24
16	-0.01	-0.08	-0.11	-0.16	-0.22
15	-0.01	-0.08	-0.10	-0.16	-0.21
14	-0.01	-0.09	-0.12	-0.18	-0.25
13	-0.02	-0.09	-0.12	-0.18	-0.26
12	-0.03	-0.09	-0.11	-0.20	-0.26
11	-0.02	-0.09	-0.11	-0.21	-0.25
10	-0.03	-0.09	-0.11	-0.16	-0.20
9	-0.02	-0.08	-0.11	-0.19	-0.23
8	-0.03	-0.09	-0.13	-0.17	-0.25
7	0.00	-0.07	-0.09	-0.25	-0.22
6	-0.02	-0.07	-0.11	-0.20	-0.23
5	-0.01	-0.08	-0.10	-0.15	-0.21
4	-0.01	-0.08	-0.12	-0.18	-0.23
3	-0.02	-0.08	-0.12	0.00	-0.26
2	-0.02	-0.08	-0.11	-0.17	-0.23
NOMINAL	0.00	0.00	0.00	0.00	0.00
AVERAGE	-0.02	-0.08	-0.11	-0.18	-0.23
STD. DEV.	0.01	0.01	0.01	0.03	0.02

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BAND TO BAND REGISTRATION - CROSS SCAN

REVERSE SCAN (UNITS ARE RFOV)
Data taken 18 September 1981

RT	B2-B1	B3-B1	B4-B1	B7-B1	B5-B1
2	0.02	-0.09	-0.13	-0.34	-0.22
3	0.01	-0.04	-0.07	-0.17	-0.20
4	0.01	-0.06	-0.05	-0.16	-0.18
5	0.00	-0.04	-0.08	-0.15	-0.19
6	0.02	-0.04	-0.08	-0.17	-0.19
7	-0.01	-0.07	-0.09	-0.26	-0.25
8	-0.03	-0.11	-0.15	-0.22	-0.27
9	-0.03	-0.09	-0.11	-0.12	-0.23
10	-0.01	-0.07	-0.11	-0.17	-0.21
11	-0.01	-0.08	-0.09	-0.17	-0.23
12	-0.01	-0.06	-0.10	-0.18	-0.23
13	0.01	-0.05	-0.08	-0.14	-0.23
14	0.01	-0.06	-0.09	-0.15	-0.22
15	-0.02	-0.09	-0.11	-0.16	-0.24
16	0.01	-0.07	-0.09	-0.16	-0.20
17	0.01	-0.06	-0.09	-0.15	-0.18
18	0.03	-0.04	-0.06	-0.16	-0.18
19	-0.01	-0.06	-0.09	-0.16	-0.23
20	0.00	-0.06	-0.09	-0.16	-0.23
21	0.00	-0.06	-0.09	-0.18	-0.24
22	0.02	-0.04	-0.06	-0.14	-0.17
23	0.01	-0.06	-0.09	-0.15	-0.19
24	-0.01	-0.07	-0.10	-0.16	-0.21
25	-0.02	-0.07	-0.10	-0.18	-0.21
26	0.00	-0.04	-0.07	-0.13	-0.18
27	0.02	-0.04	-0.06	-0.12	-0.17
28	0.01	-0.05	-0.07	0.00	-0.18
29					
30	0.03	-0.02	-0.05	-0.16	-0.19
NOMINAL	0.00	0.00	0.00	0.00	0.00
AVERAGE	0.00	-0.06	-0.09	-0.17	-0.21
STD. DEV.	0.02	0.02	0.02	0.04	0.03

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FORWARD SCAN (UNITS ARE RFOV)
Data taken 18 September 1981

RT	B1	B2	B3	B4	B7	B5
30	1.58	1.97	2.00	2.00	1.86	1.97
29	1.97	1.94	2.01	2.00	1.86	1.95
28	1.97	1.95	2.02	2.00	1.87	1.95
27	1.98	1.96	2.01	2.00	1.86	1.96
26	1.98	1.96	2.01	1.99	1.88	1.96
25	1.97	1.97	2.01	2.00	1.87	1.96
24	1.97	1.97	2.01	2.00	1.86	1.96
23	1.97	1.97	2.01	2.00	1.85	1.95
22	1.97	1.96	2.01	1.99	1.87	1.95
21	1.97	1.96	2.02	2.00	1.87	1.95
20	1.96	1.98	2.01	2.00	1.86	1.96
19	1.96	1.97	2.01	1.99	1.88	1.96
18	1.96	1.98	2.01	2.00	1.87	1.96
17	1.96	1.99	2.01	2.00	1.87	1.96
16	1.96	1.97	2.01	2.00	1.86	1.96
15	1.97	1.99	2.01	2.00	1.88	1.96
14	1.97	1.98	2.01	2.00	1.87	1.96
13	1.96	1.97	2.01	2.00	1.86	1.95
12	1.96	1.96	2.01	1.99	1.67	1.96
11	1.97	1.95	2.01	2.00	1.87	1.96
10	1.97	1.97	2.01	2.00	1.87	1.96
9	1.97	1.95	2.01	2.00	1.85	1.96
8	1.97	1.95	2.01	2.00	1.86	1.96
7	1.97	1.95	2.01	2.00	1.87	1.96
6	1.98	1.95	2.01	2.00	1.88	1.96
5	1.98	1.93	2.02	2.00	1.85	1.96
4	1.98	1.95	2.02	2.00	1.90	1.96
3	1.97	1.96	2.03	2.01	1.87	1.97
2	1.98	1.95	2.03	2.00	1.60	1.96
NOMINAL	2.00	2.00	2.00	2.00	2.00	2.00
AVERAGE	1.97	1.96	2.01	2.00	1.87	1.96
STD. DEV	0.01	0.01	0.01	0.00	0.02	0.00

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BAND TO BAND REGISTRATION - EVEN TO ODD CHANNEL

5/82

REVERSE SCAN (UNITS ARE RFOV)
Data taken 18 September 1981

RT	B1	B2	B3	B4	B7	B5
2	-3.01	-3.02	-2.98	-2.99	-2.93	-2.85
3	-3.00	-3.01	-2.97	-2.98	-2.92	-2.84
4	-3.00	-3.02	-2.97	-2.98	-2.91	-2.85
5	-2.99	-3.00	-2.98	-3.00	-2.70	-2.85
6	-3.01	-3.02	-2.98	-2.99	-2.91	-2.85
7	-2.98	-3.01	-2.98	-2.99	-2.90	-2.84
8	-3.01	-3.02	-2.96	-2.99	-2.91	-2.84
9	-3.00	-3.01	-2.96	-2.99	-2.92	-2.84
10	-2.99	-3.02	-2.96	-2.98	-2.91	-2.83
11	-2.99	-3.02	-2.98	-2.99	-2.92	-2.84
12	-2.99	-3.02	-2.97	-2.99	-2.92	-2.85
13	-2.99	-3.00	-2.97	-2.99	-2.71	-2.84
14	-2.99	-3.01	-2.97	-2.99	-2.92	-2.84
15	-2.99	-3.01	-2.97	-2.99	-2.92	-2.85
16	-2.99	-3.02	-2.97	-2.99	-2.92	-2.84
17	-2.98	-3.01	-2.96	-2.99	-2.92	-2.84
18	-3.00	-3.01	-2.97	-2.99	-2.91	-2.85
19	-3.00	-3.01	-2.97	-2.99	-2.93	-2.95
20	-2.98	-3.00	-2.97	-2.99	-2.91	-2.83
21	-2.99	-3.01	-2.96	-2.99	-2.91	-2.84
22	-2.98	-3.00	-2.96	-2.98	-2.92	-2.84
23	-2.99	-3.01	-2.97	-2.99	-2.92	-2.84
24	-3.00	-3.02	-2.96	-2.99	-2.93	-2.53
25	-2.97	-3.01	-2.97	-2.99	-2.88	-2.84
26	-3.02	-3.01	-2.99	-3.00	-2.89	-2.85
27	-3.02	-3.03	-2.97	-2.99	-2.90	-2.86
28	-2.99	-3.04	-2.95	-2.99	-2.92	-2.84
29						
30	-3.01	-3.04	-2.99	-2.99	-2.93	-2.85
NOMINAL	-3.00	-3.00	-3.00	-3.00	-3.00	-3.00
AVERAGE	-3.00	-3.01	-2.97	-2.99	-2.91	-2.84
STD. DEV.	0.01	0.01	0.01	0.00	0.04	0.01

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SCAN LINEARITY

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ALONG SCAN PROFILE

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FORWARD SCAN PROFILE
SME-1 SAM MODE

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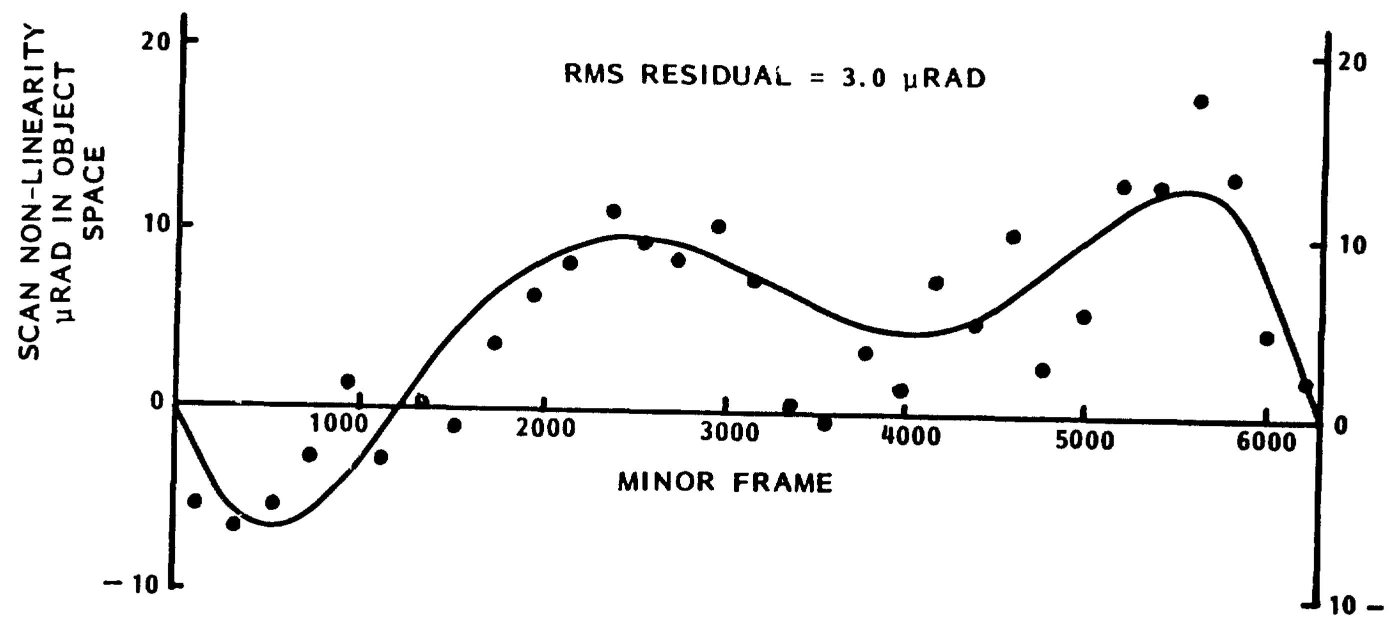

REVERSE SCAN PROFILE
SME-1 SAM MODE

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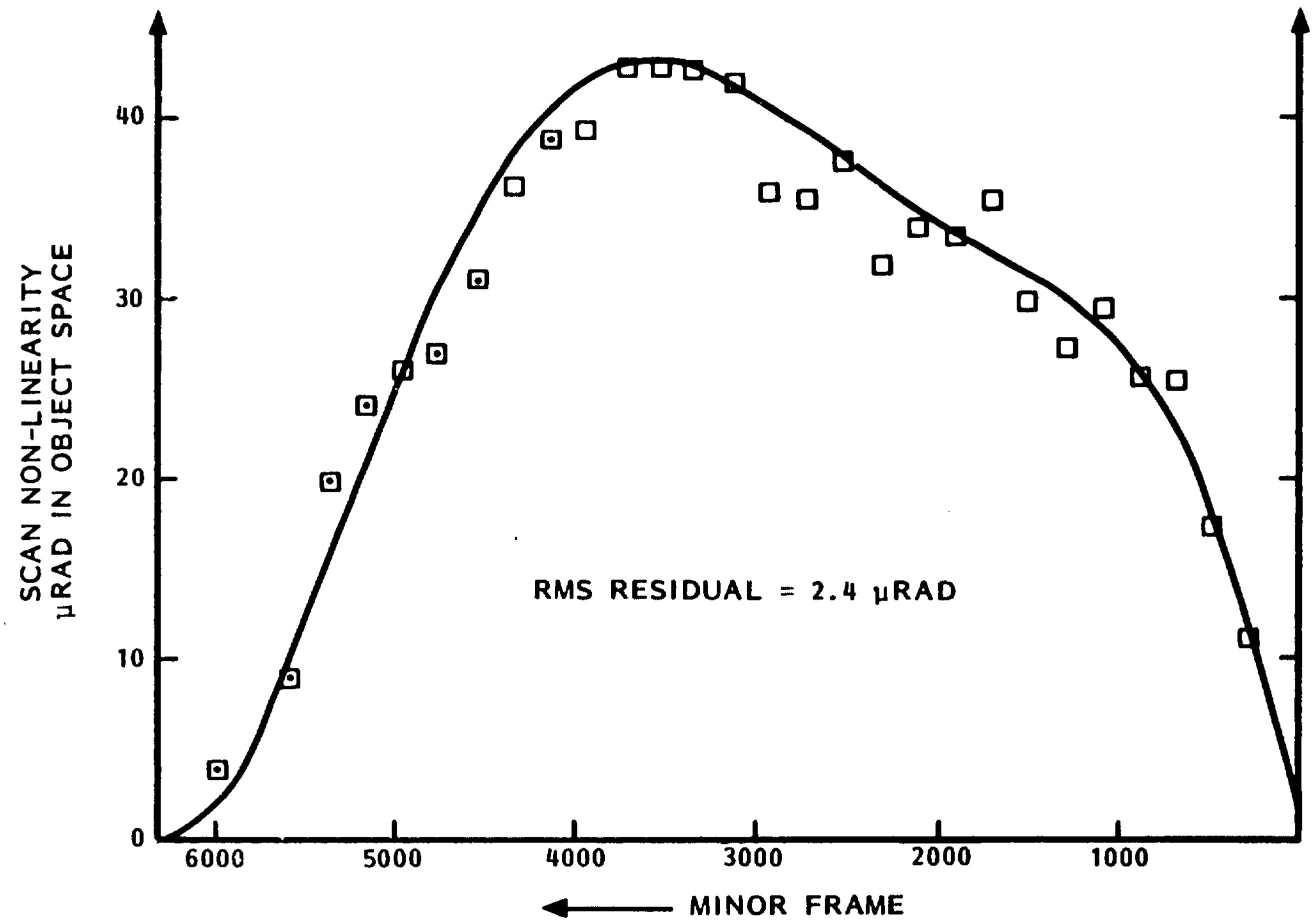

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QUALITY OF ALONG SCAN DATA FOR FULL BL19/20 COLLECT

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HUGHES AIRCRAFT COMPANY

- EACH DATA POINT IS THE AVERAGE OF FIVE SCANS
- SCAN TO SCAN REPEATABILITY (AFTER LINE LENGTH CORRECTION) IS ± 4 μrad RMS
- SCAN TO SCAN REPEATABILITY DOES NOT DEPEND ON POSITION WITHIN THE SCAN
- RESIDUAL BETWEEN AVERAGED DATA POINTS AND COMPUTED PROFILE IS ± 3 μrad RMS

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PARAMETERS FOR COMPUTATION OF THE ALONG SCAN PROFILE

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	FORWARD SCAN								REVERSE SCAN								
	a_0	a_1	a_2	a_3	a_4	a_5	$PHIf_0$	W_F	a_0	a_1	a_2	a_3	a_4	a_5	$PHIr_0$	W_R	K'_0
SME-1 SAM MODE	0.0	-3.1507E-8	4.5738E-11	-2.0410E-14	3.6950E-18	-2.3511E-22	-4.4 E-6	42.5146E-6	3.28 E-5	5.6926E-8	-4.3551E-11	1.7302E-14	-3.1186E-18	1.9711E-22	34.6 E-6	42.5127E-6	0.499933
SME-2 SAM MODE	0.0	-3.6085E-8	4.5812E-11	-2.0071E-11	3.6306E-18	-2.3084E-22	-9.4 E-6	42.5196E-6	3.44 E-5	5.3268E-8	-4.4062E-11	1.7826E-14	-3.2106E-18	2.0287E-22	32.3 E-22	42.5187E-6	0.499911

UNITS:

- a_i IN rad/(mf)^i
- $PHIf_0$, $PHIr_0$ IN rad
- W_F, W_R IN rad/mf
- K'_0 IS A PURE NUMBER

- a_0 IS CHOSEN SO THAT THE FORWARD AND REVERSE SCAN ANGLES ARE CONSISTENT FOR BAND 4 CHANNEL 9
- THE DESIGN SCAN RATE IS 42.50E-6 rad/MF

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COMPUTATION OF THE ALONG SCAN PROFILE

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FOR FORWARD SCANS

$$\theta(mf) = W_F \cdot mf^* + \sum_{i=0}^{5} C_i \, (mf^*)^i + 4 \cdot \Phi_{mid} \quad \frac{mf^* \, (6320 - mf^*)}{6320^2}$$

FOR REVERSE SCANS

$$\theta(mf) = W_R \cdot (6320 - mf^*) + \sum_{i=0}^{5} C_i \, (mf^*)^i + 4 \cdot \Phi_{mid} \quad \frac{mf^* \, (6320 - mf^*)}{6320^2}$$

WHERE

$$mf^* = \frac{mf}{1 + \dfrac{\Delta TSCAN}{TSCAN}}$$

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CROSS SCAN PROFILE

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CROSS SCAN PROFILE NONLINEARITIES

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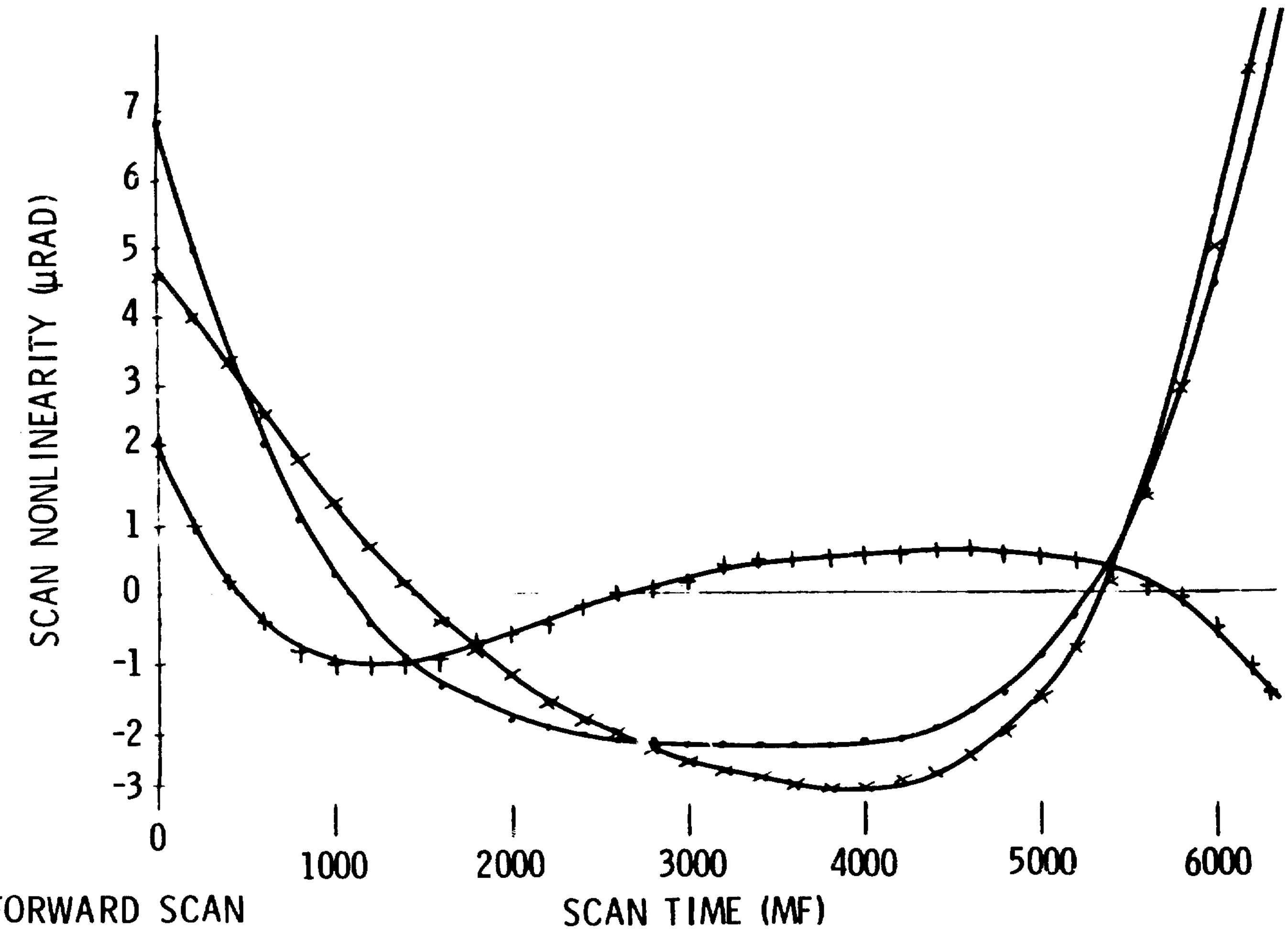

• FORWARD SCAN
X REVERSE SCAN
+ FORWARD - REVERSE (2x NON NESTED COMPONENT)

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CROSS SCAN PROFILE
5TH ORDER POLYNOMIAL COEFFICIENTS

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	FORWARD SCAN	REVERSE SCAN
C_0	-0.000287	-0.000276
C_1	-1.014827E-8	-1.628688E-8
C_2	4.295777E-12	8.563377E-12
C_3	-7.930246E-16	-2.248363E-15
C_4	4.174148E-20	2.998088E-19
C_5	2.675552E-24	-1.531221E-23
W_C	9.286E-8	9.286E-8

$$\Phi_{CS} = \sum_{i=0}^{5} C(i)MF^{i} \qquad \Phi_{CS} \text{ (radians)}$$

$$W_C = 9.287E\text{-}8 \text{ rad/MF} = 9.66E\text{-}3 \text{ rad/sec}$$

$$1MF = 9.611 \ \mu\text{sec}$$

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TM Geometric Processing — Flight Segment

Eric Beyer

GEOMETRIC CORRECTION OVERVIEW

- FLIGHT SEGMENT
  - ATTITUDE DEVIATIONS
  - THEMATIC MAPPER
  - DATA COORDINATION
- TM GROUND PROCESSING
  - PAYLOAD CORRECTION PROCESSING
  - CONTROL POINT PROCESSING
  - GEOMETRIC CORRECTION PROCESSING
  - GEOMETRIC CORRECTION PROCESSING (RESAMPLING)
- SYSTEM PERFORMANCE
- TM END-TO-END GEOMETRIC PERFORMANCE TEST

UNITS

TM PIXEL $= 42.5\,\mu$RAD $= 8.77$ ARC-SEC $\Rightarrow$ 30 METERS AT 705.3 KM

MSS PIXEL $= 117.2\,\mu$RAD $= 24.17$ ARC-SEC $\Rightarrow$ 82.7 METERS AT 705.3 KM

$1\,\mu$RAD $\Rightarrow$ .71 METER AT 705.3

1 ARC-SEC $\Rightarrow$ 3.4 METER AT 705.3

1 ARC-SEC $= 4.85\,\mu$RAD

SINGLE SCENE ACCURACY REQUIREMENT

$$0.3 \text{ PIXEL TEMPORAL } (90\%) \times \frac{42.5\mu \text{ RAD}}{\text{PIXEL}} \times \frac{(1\sigma)}{1.645(90\%)} \times \frac{\text{SINGLE SCENE}}{\sqrt{2}\text{ TEMPORAL}} = 5.48\,\mu\text{RAD} = 1.13 \text{ ARC SEC } (1\sigma)$$

$= 3.9$ METER (1σ)

AT 705.3 KM

3

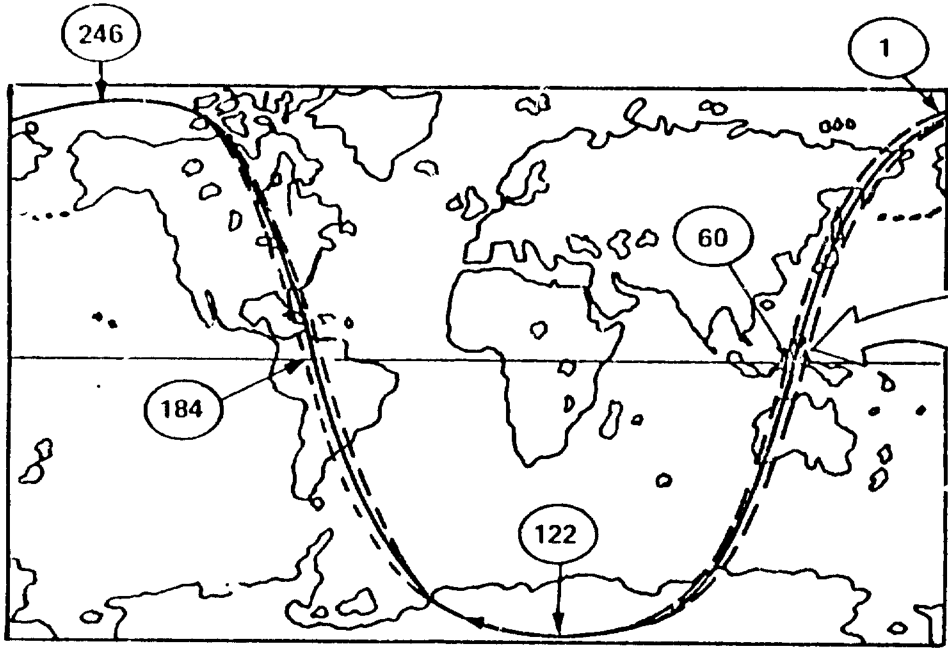
GEOMETRIC CORRECTION

- CORRECTION DATA GENERATION
  - LOCATE TM DETECTOR SAMPLES ON THE OUTPUT PROJECTION SYSTEM

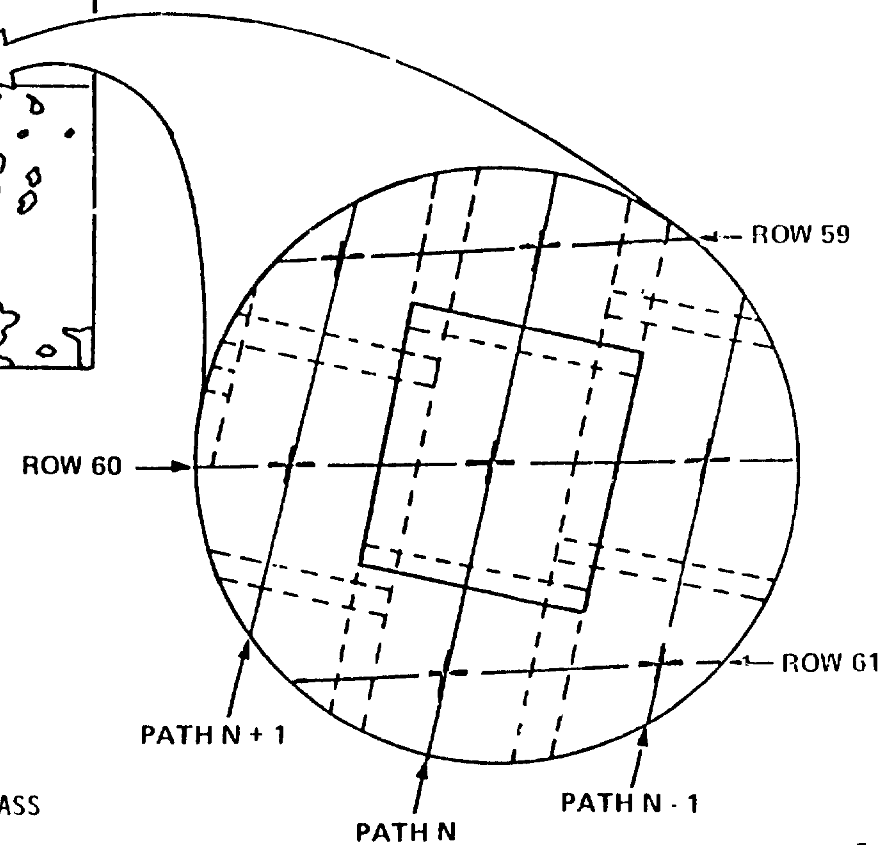
- PRODUCT GENERATION (RESAMPLING)
  - USING CORRECTION DATA TO RESAMPLE TM DETECTOR SAMPLES ONTO OUTPUT PROJECTION SYSTEM

4

WORLDWIDE REFERENCE SYSTEM



- 233 PATHS
- 248 ROWS
- PATH 1 CROSSES EQUATOR AT 64.6°W



- WRS LAT., LONG FIXED
- TWO MAP PROJECTIONS
  - SPACE OBLIQUE MERCATOR (SOM)
  - UNIVERSAL TRANSVERSE MERCATOR (UTM)
    OR
    POLAR STEREOGRAPHIC
- OUTPUT PROJECTION SYSTEM
  - FIXED ROTATION ANGLE FOR EACH WRS SCENE AND MAP PROJECTION
  - INTEGER PIXEL HORIZONTAL SHIFT FOR EACH SCENE PASS
- STANDARD GEOID

FIGURE 1-1

CORRECTION DATA GENERATION CONCEPT

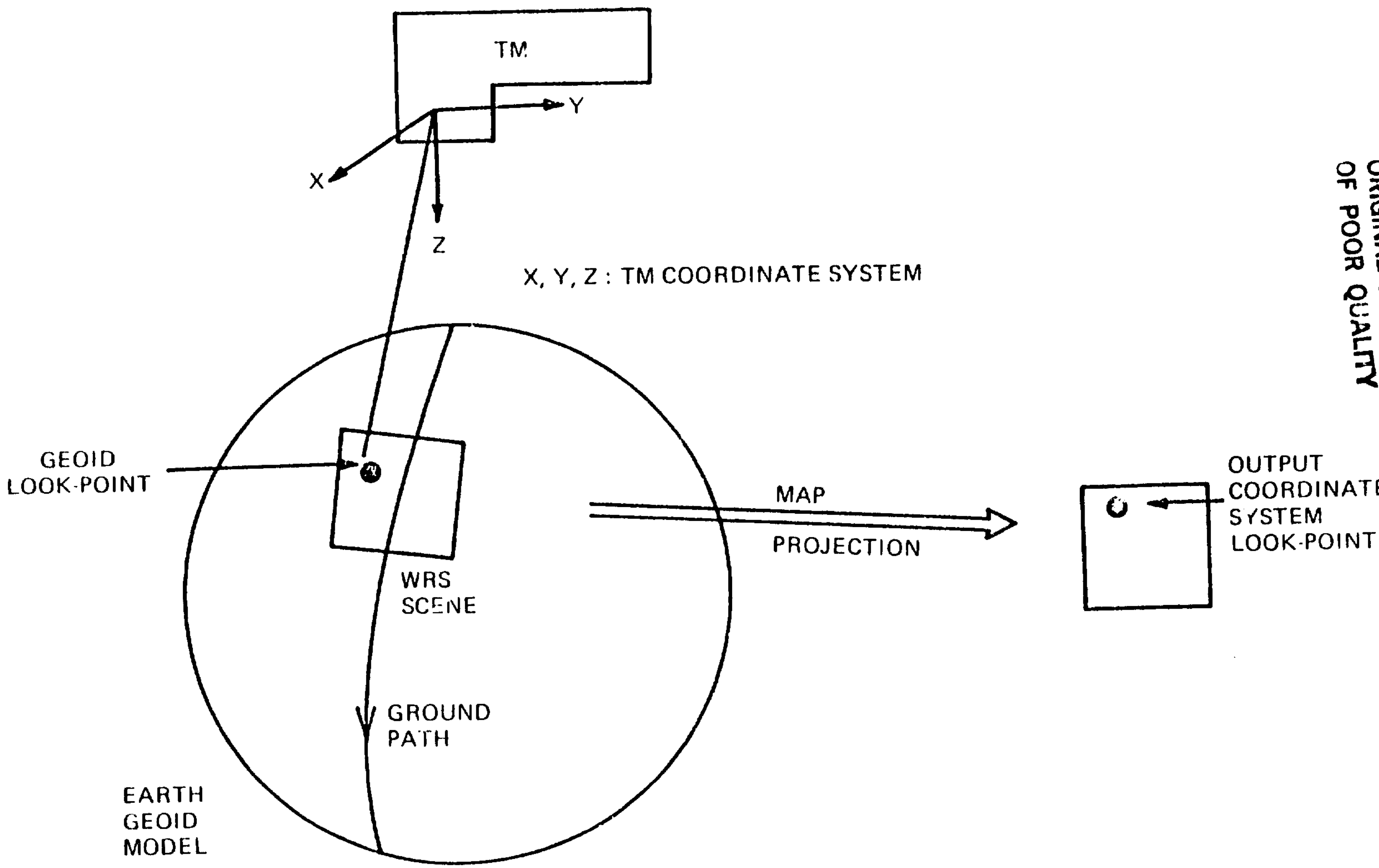


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FIGURE 1-2

RESAMPLING CONCEPT

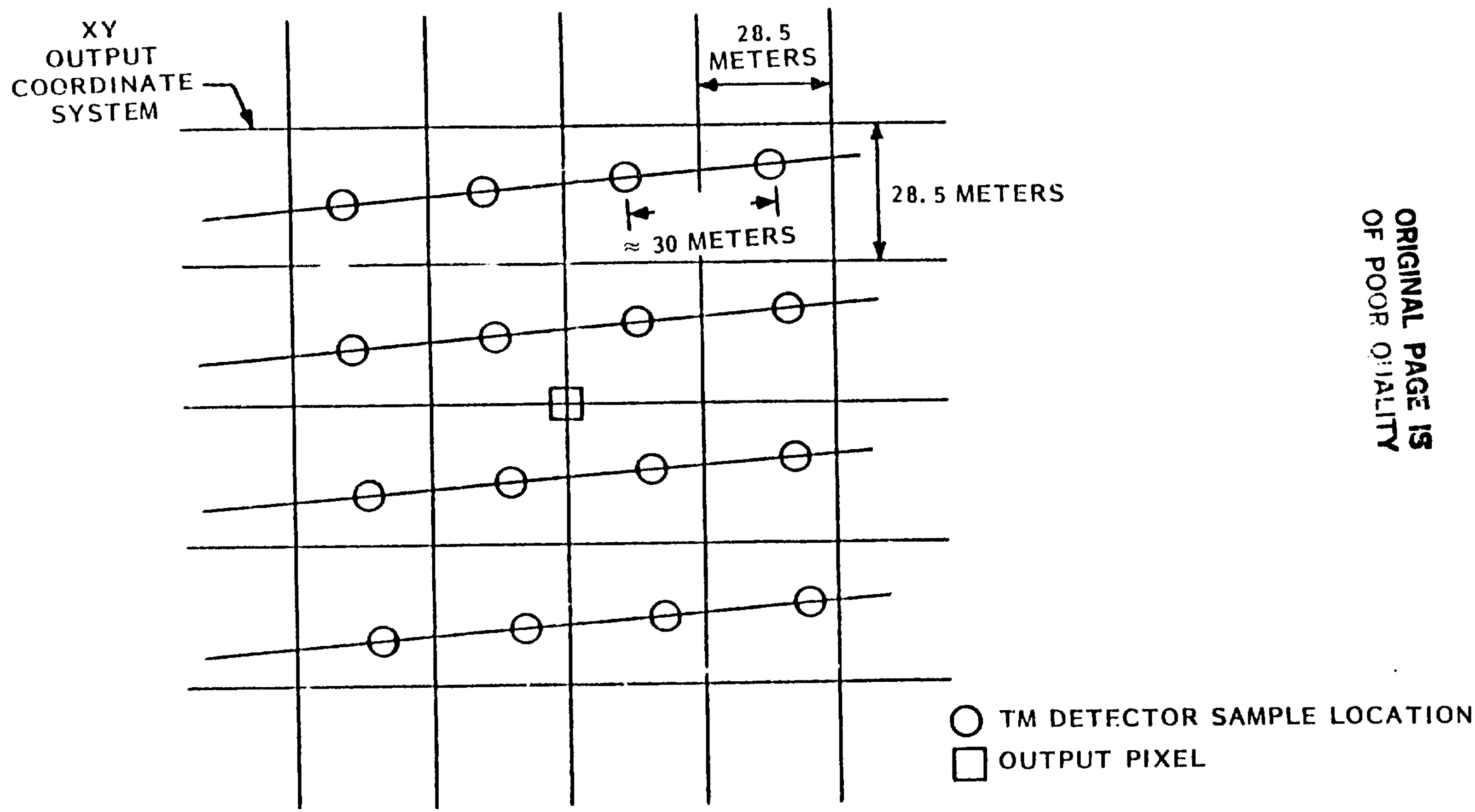

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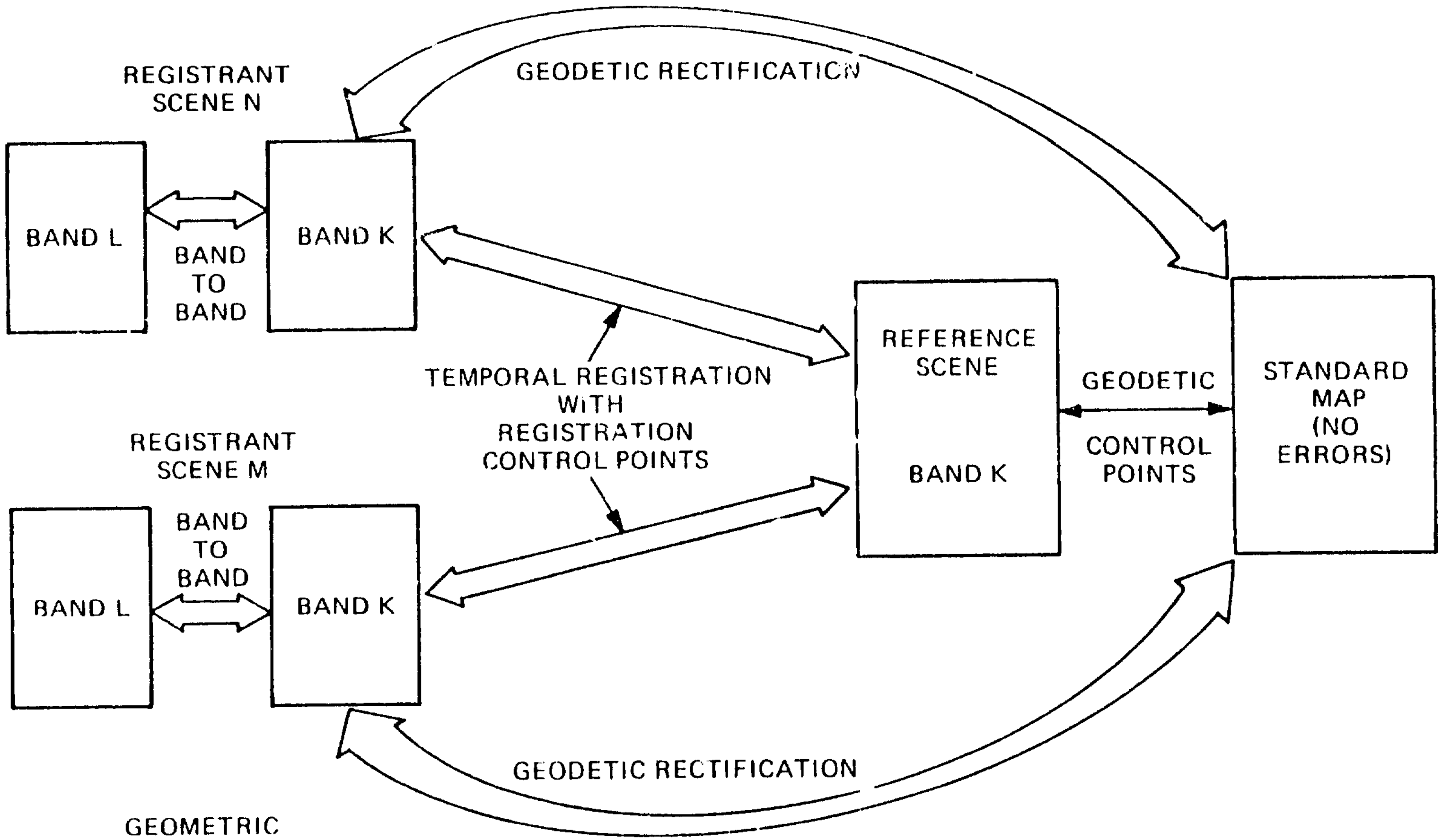
FIGURE 1-3

GEOMETRIC ACCURACY SPECIFICATIONS



GEOMETRIC CORRECTION REQUIREMENTS 90% OF THE TIME

GEODETIC	0.5 PIXEL
TEMPORAL	0.3 PIXEL (REGISTRANT TO REFERENCE)
BAND-TO-BAND	0.3 PIXEL (BETWEEN PRIMARY AND COLD FOCAL PLANES)
	0.2 PIXEL (WITHIN EACH FOCAL PLANE)

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SUMMARY OF KEY
GEOMETRIC CORRECTION REQUIREMENTS (ACCURACY)

GEODETIC RECTIFICATION

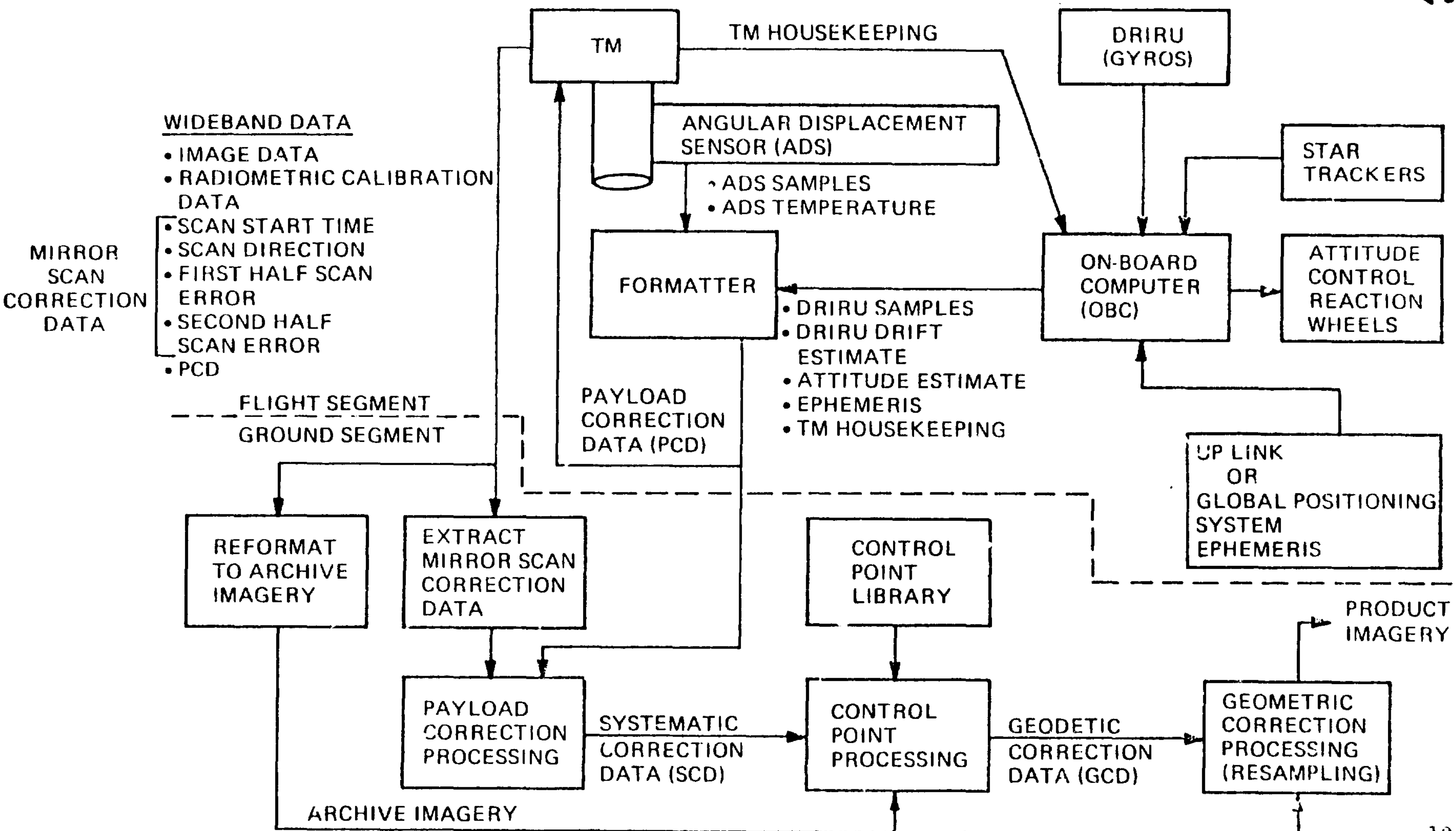
- 0.5 PIXEL (90% OF THE TIME)
- REFERENCE TO STANDARD MAP
- ASSUME ACCURATE GROUND CONTROL POINTS
- ADEQUATE NUMBER OF GROUND CONTROL POINTS
- VERIFIED OVER AREAS WITH NO TOPOGRAPHICAL VARIATIONS

TEMPORAL REGISTRATION

- 0.3 PIXEL (90% OF THE TIME)
- ADEQUATE INSTRUMENT PERFORMANCE
- ADEQUATE NUMBER OF GROUND CONTROL POINTS

FIGURE 1-4

LANDSAT D TM GEOMETRIC CORRECTION SYSTEM OVERVIEW



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FLIGHT SEGMENT

ATTITUDE DEVIATIONS

THEMATIC MAPPER

DATA COORDINATION

FIGURE 2-1

LANDSAT D FLIGHT SEGMENT

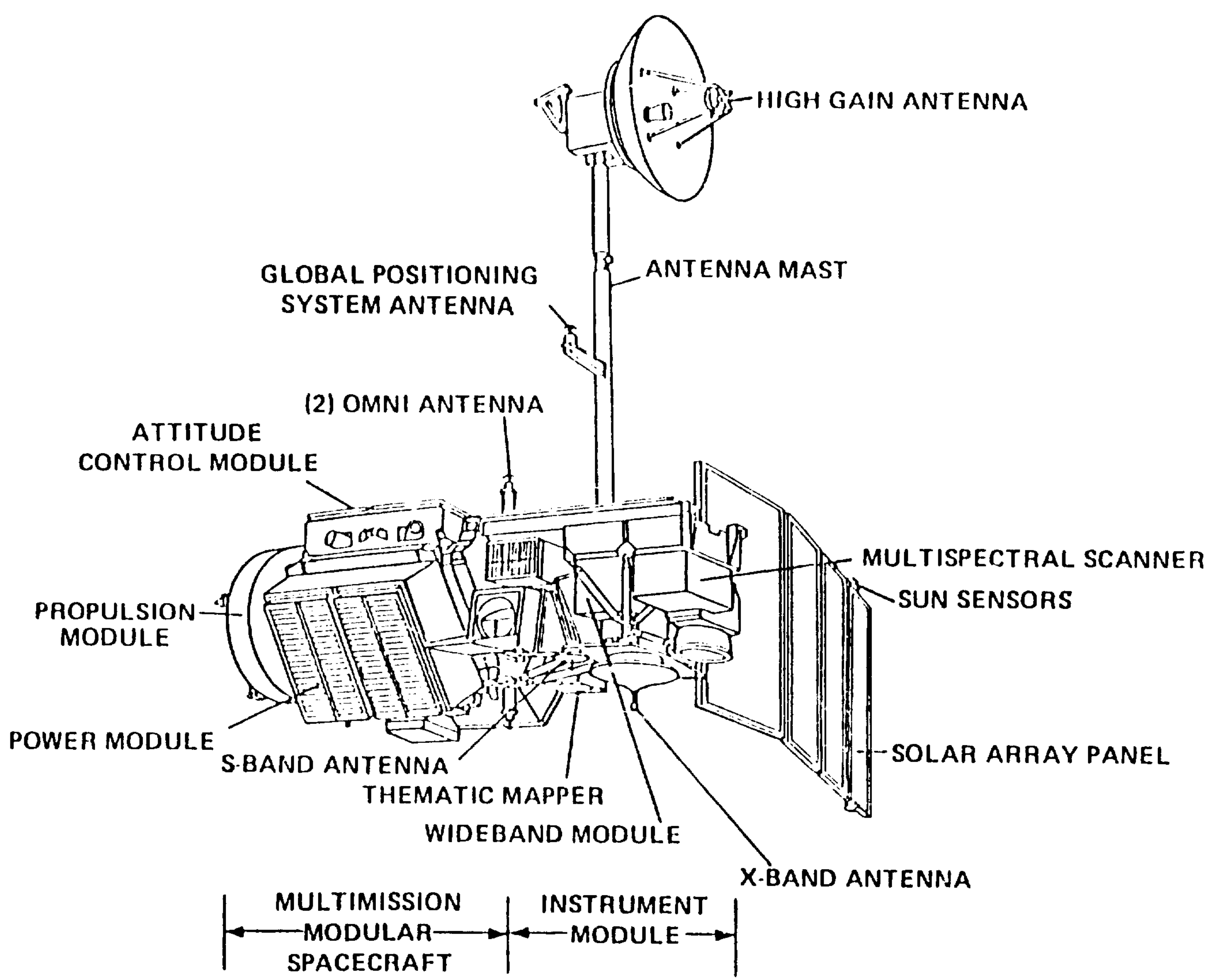


FIGURE 2-2

LANDSAT-D ORBIT

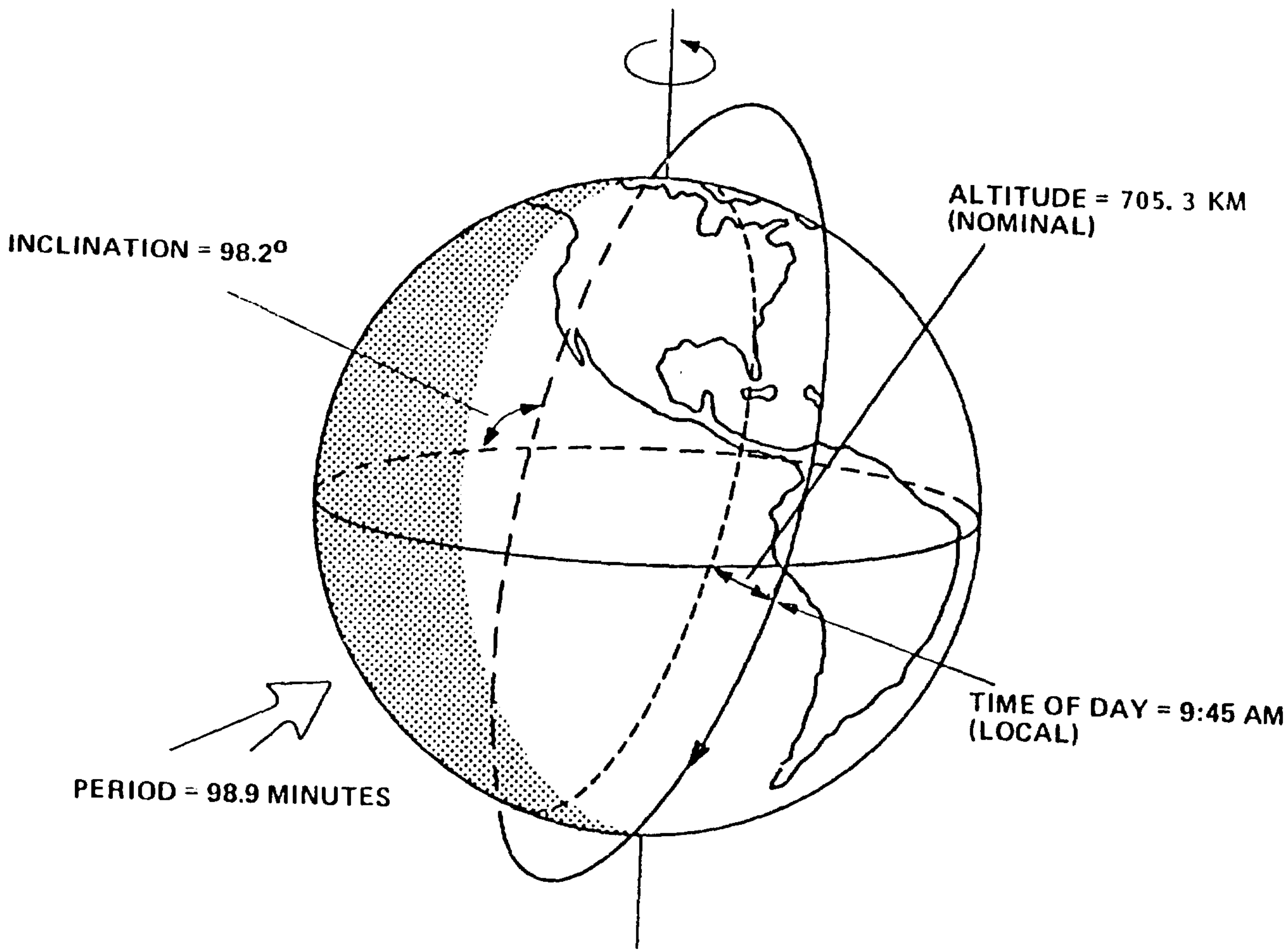
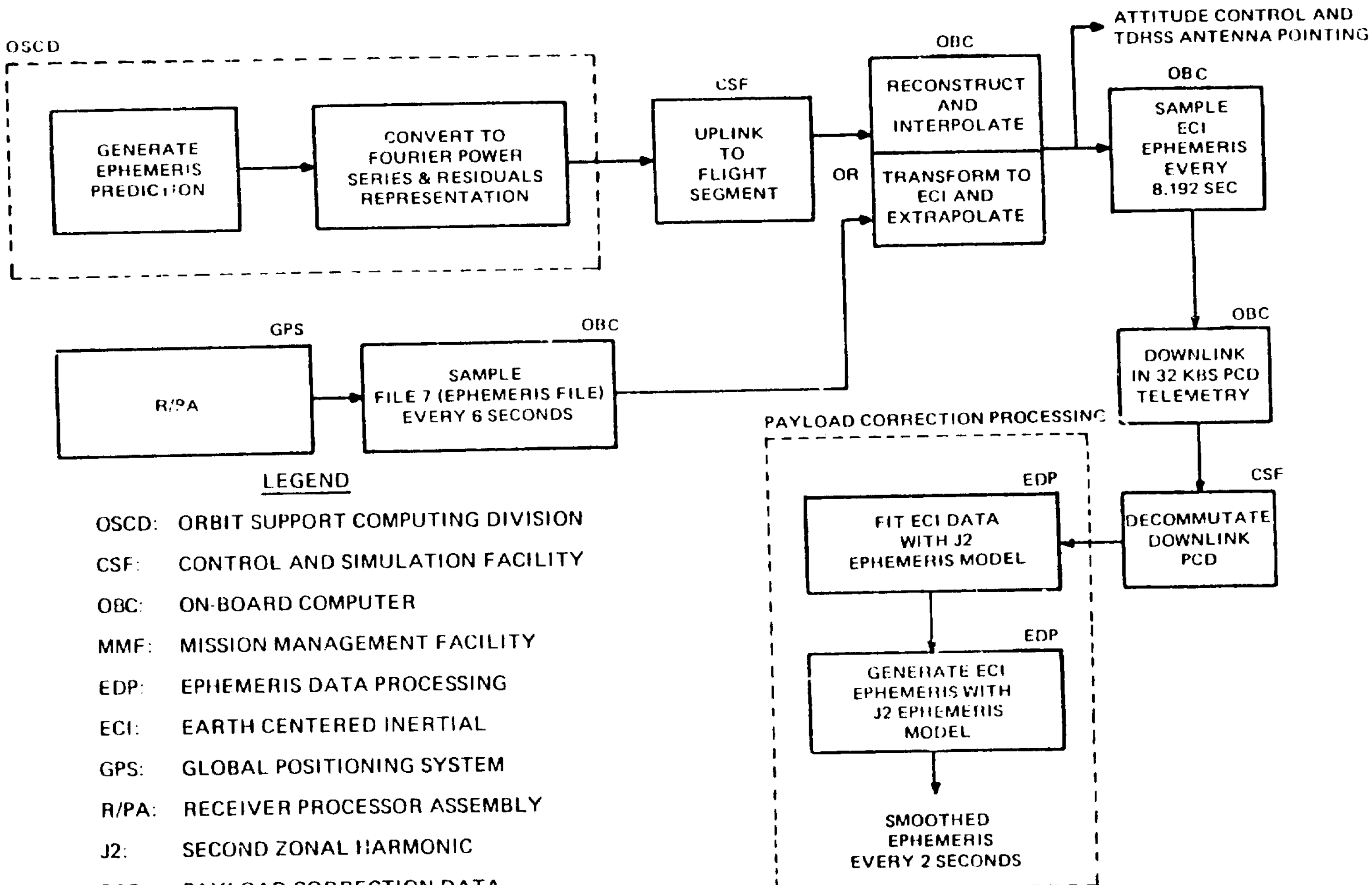


FIGURE 2-3

SYSTEM EPHEMERIS DATA FLOW FOR TM GEOMETRIC CORRECTION



LEGEND

OSCD: ORBIT SUPPORT COMPUTING DIVISION
CSF: CONTROL AND SIMULATION FACILITY
OBC: ON-BOARD COMPUTER
MMF: MISSION MANAGEMENT FACILITY
EDP: EPHEMERIS DATA PROCESSING
ECI: EARTH CENTERED INERTIAL
GPS: GLOBAL POSITIONING SYSTEM
R/PA: RECEIVER PROCESSOR ASSEMBLY
J2: SECOND ZONAL HARMONIC
PCO: PAYLOAD CORRECTION DATA
TDRSS: TRACKING DATA RELAY SATELITE SYSTEM

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EPHEMERIS ACCURACY AND VARIATION

- ORBIT SUPPORT COMPUTING DIVISION EPHEMERIS ERROR

(1σ AFTER 2 DAYS)

	POSITION (METERS)	VELOCITY (METERS/SEC)
ALONG TRACK	500*	.163
CROSS TRACK	100	.065
RADIAL	33	.650*

*GSFC SPEC

- VARIATION FROM NOMINAL
  - ALTITUDE (705.3 KM ORBIT): 696 TO 741 KM OVER EARTH; RANGE OF 19 KM OVER ANY FIXED LATITUDE
  - CROSS TRACK: ± 4 KM AT THE EQUATOR
  - INCLINATION: 98.21 ± .045 DEGREES

- SPACECRAFT CLOCK ACCURACY ± 20 MILLISECONDS

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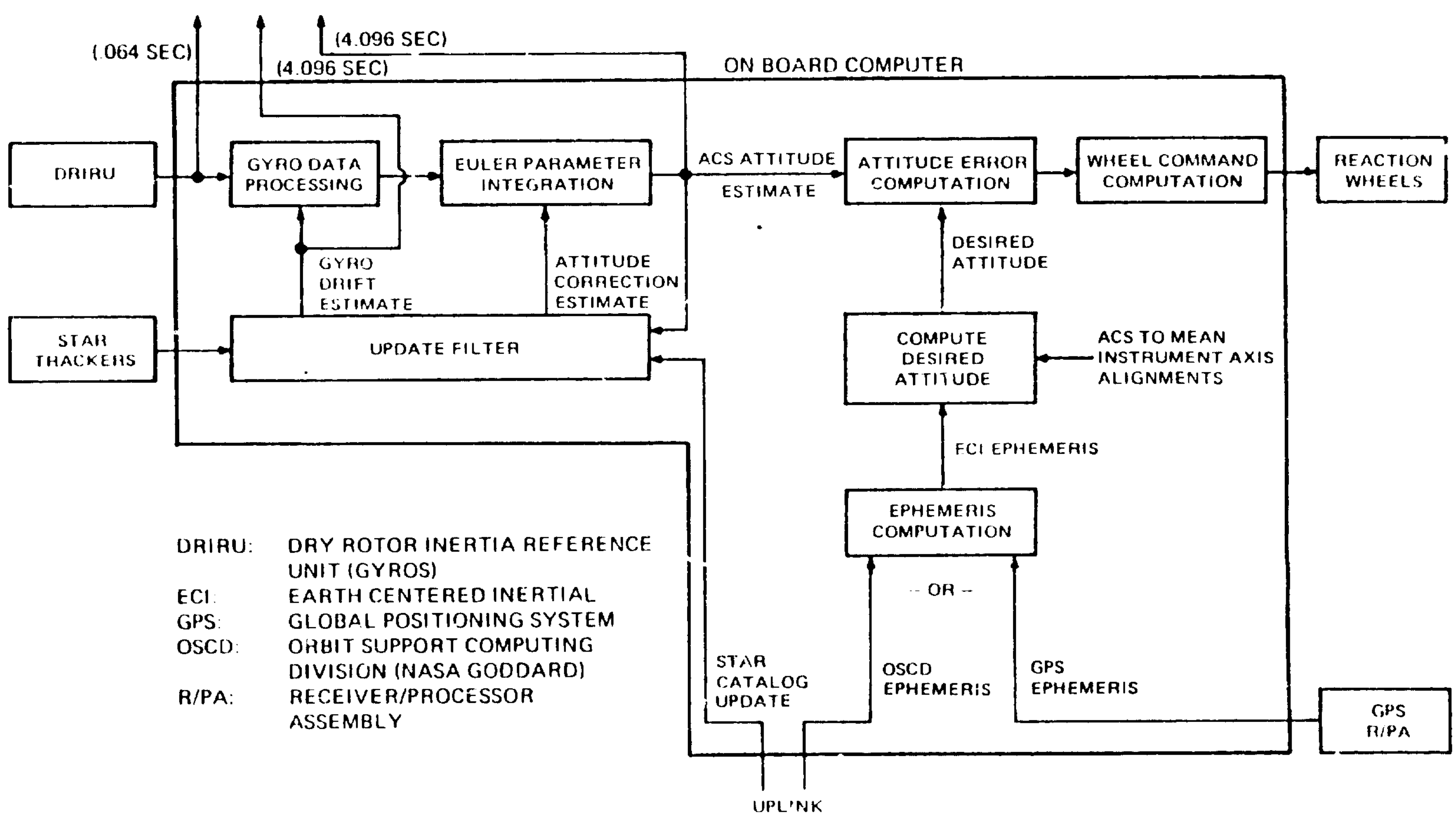
FIGURE 2-4

ATTITUDE CONTROL SUBSYSTEM (ACS)

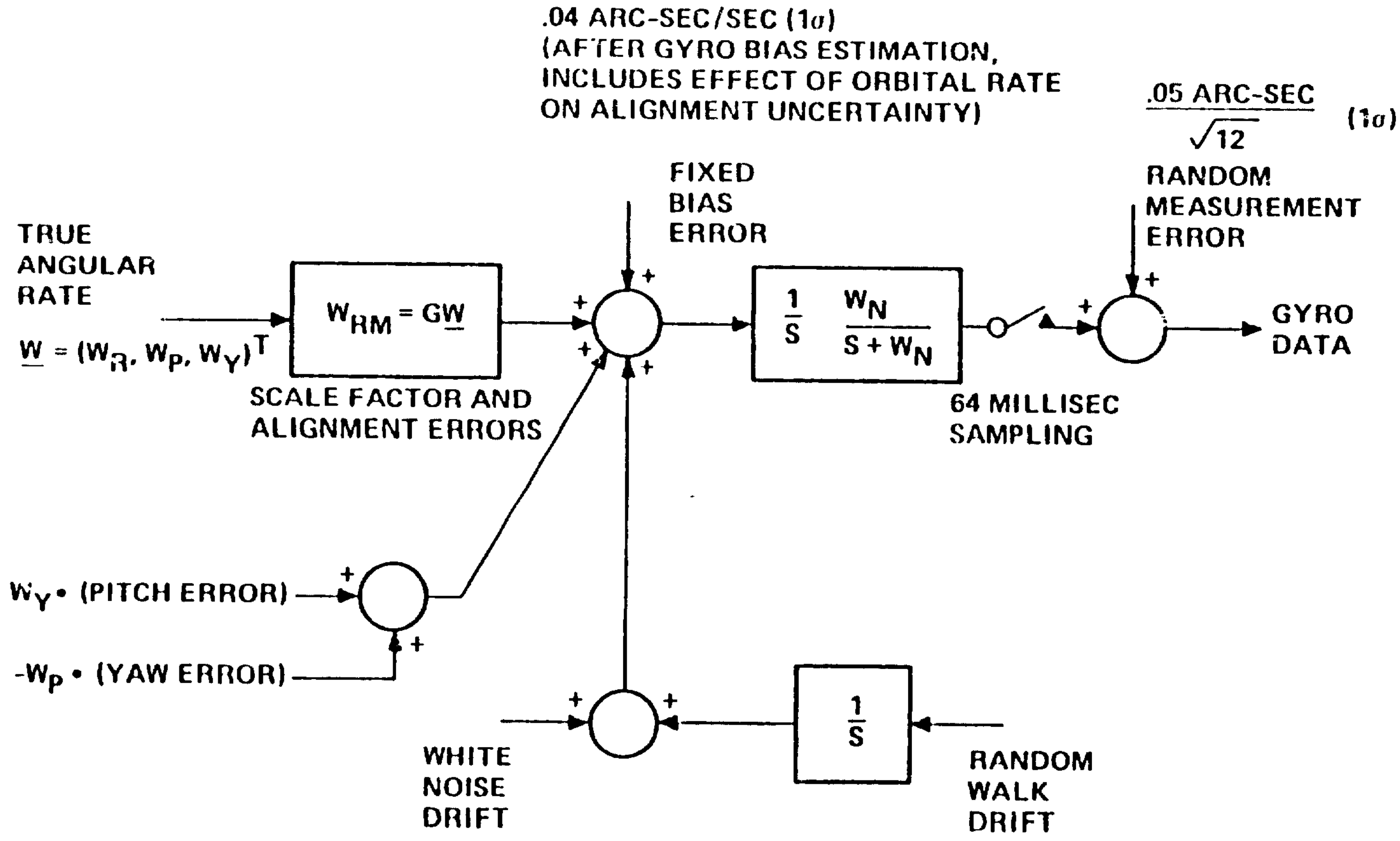
NORMAL OPERATING MODE FUNCTIONAL BLOCK DIAGRAM



DRIRU:	DRY ROTOR INERTIA REFERENCE UNIT (GYROS)
ECI:	EARTH CENTERED INERTIAL
GPS:	GLOBAL POSITIONING SYSTEM
OSCD:	ORBIT SUPPORT COMPUTING DIVISION (NASA GODDARD)
R/PA:	RECEIVER/PROCESSOR ASSEMBLY

FIGURE 2-5

LOW FREQUENCY ATTITUDE ERROR DYNAMICS

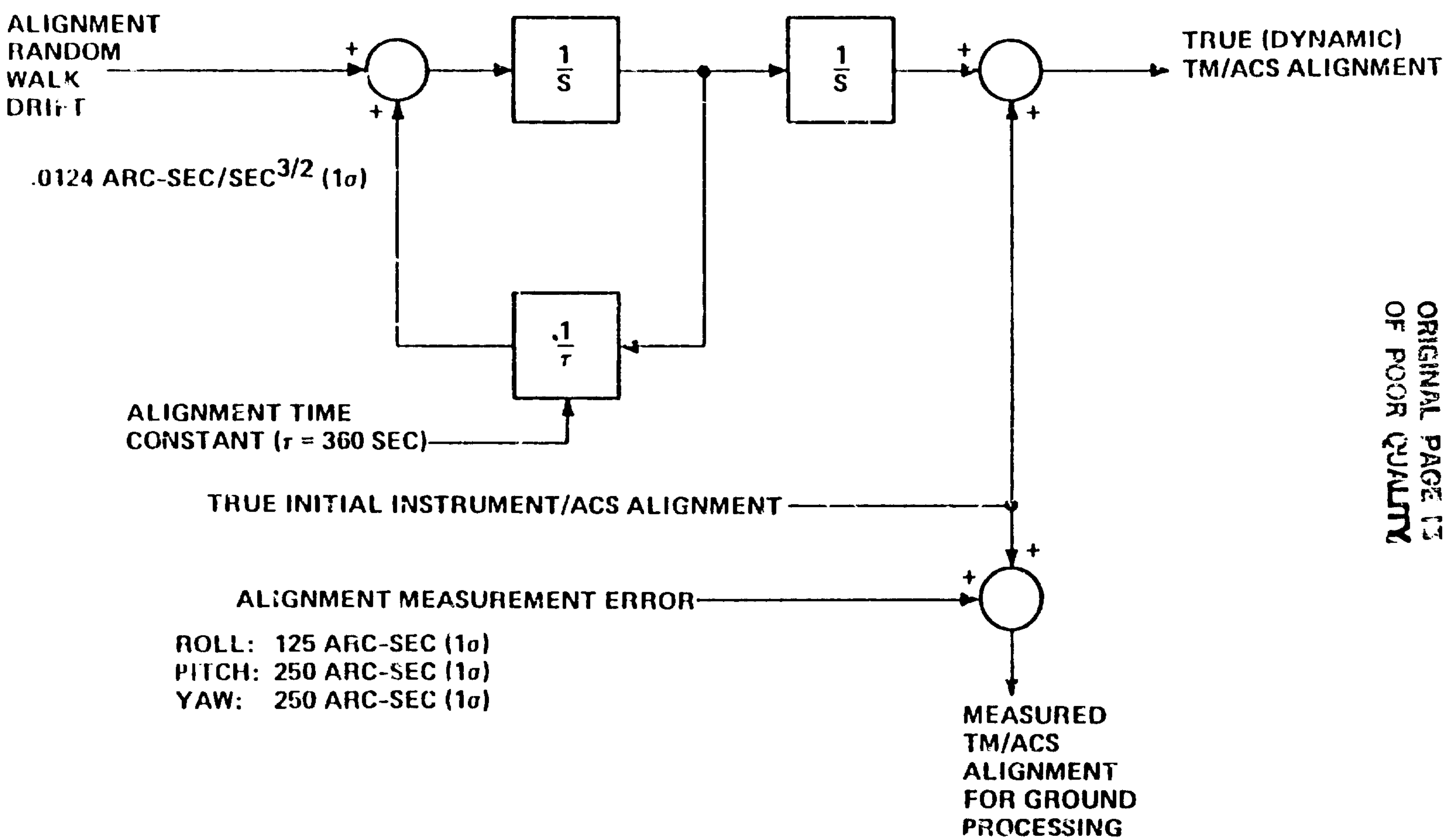


[ONLY ROLL AXIS MODEL SHOWN]

W_R, W_P, W_Y: ROLL, PITCH YAW ANGULAR RATES

FIGURE 2-6

SPACECRAFT ALIGNMENT DYNAMICS
(ACS TO TM OPTICAL AXIS)



ACS: ATTITUDE CONTROL SYSTEM

FLIGHT SEGMENT ATTITUDE DEVIATIONS

SPACECRAFT ATTITUDE DEVIATIONS

LANDSAT-D VEHICLE

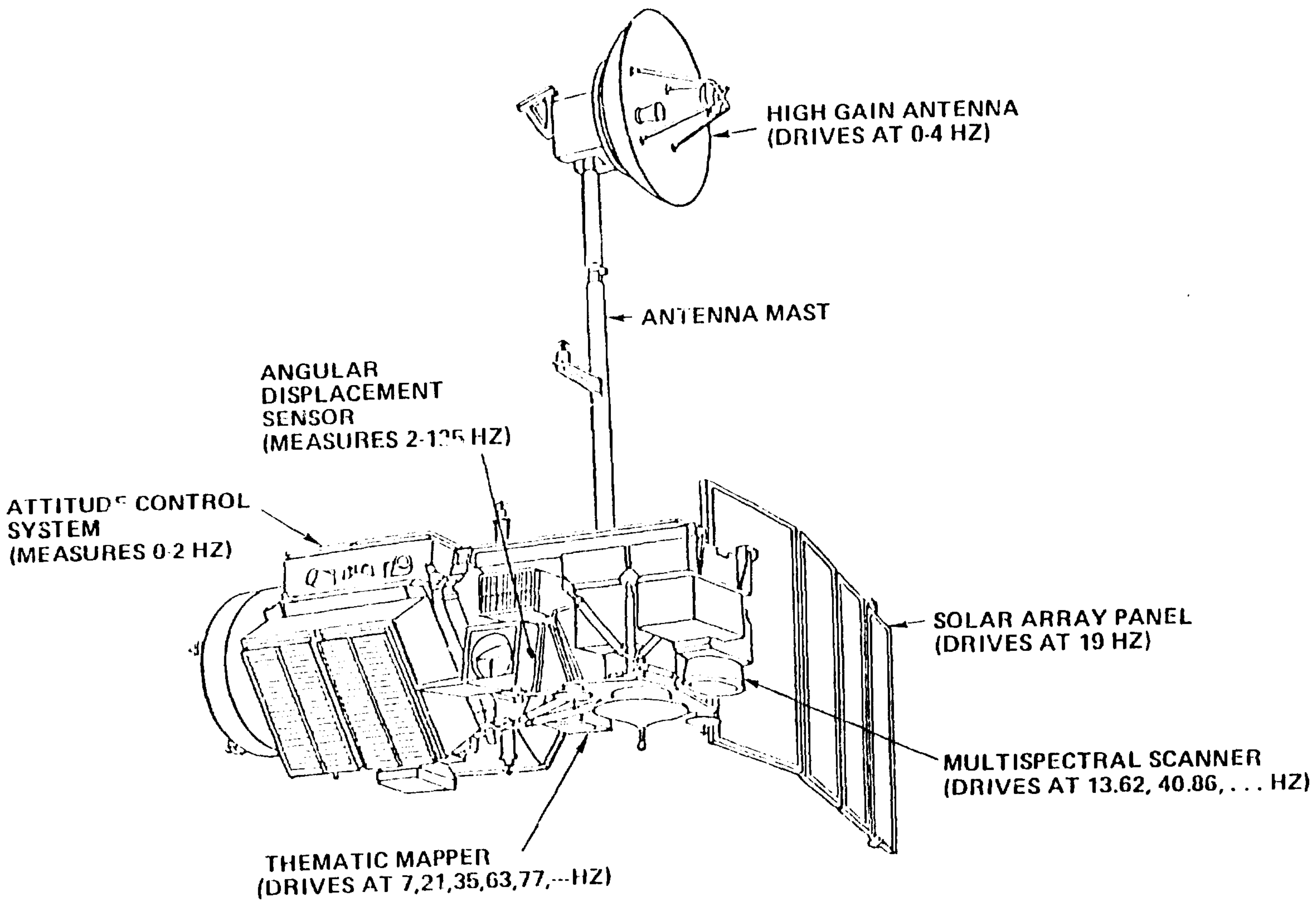


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TABLE 2-1

AMPLITUDES OF TM AND MSS SCAN MIRROR TORQUE COMPONENTS

TM		MSS	
FREQUENCY (Hz)	AMPLITUDE (IN-LBS)	FREQUENCY (Hz)	AMPLITUDE (IN-LBS)
7	43.343	13.620	40.398
21	41.543	40.860	39.507
35	39.106	68.100	37.770
49	33.341	95.340	35 269
63	27.663	122.580	32.122
77	21.547	149.820	28.476
91	15.476	177.060	24.494
105	9.8845	204.300	20.351
119	5.1200	231.540	16.217
		258.780	12.253
		286.020	8.601
		313.260	5.373
		340.50	2.651

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ATTITUDE ERROR

(AT THE TM)

FREQUENCY RANGE	ERROR MAGNITUDE (ARC-SEC)		COMMENT
0 - 0.01 Hz	36 (1σ)		ALL AXES, ATTITUDE CONTROL ERROR
0.01 - 0.4 Hz	10 (1σ)		ALL AXES, TDRSS ANTENNA DRIVE ERROR
0.4 - 7 Hz	0.3 (1σ)		ALL AXES, TDRSS ANTENNA DRIVE ERROR
	BASELINE MODEL (.01 DAMPING)	WORST CASE DESIGN	
>7 Hz	R 0.93 (1σ)	20.0 (PEAK)	ADS LIMIT IS 50 ARC-SEC
	P 0.20 (1σ)	2.2 (PEAK)	LIMITS JITTER GAP TO LESS THAN ONE PIXEL
	Y 0.30 (1σ)	16.8 (PEAK)	
ADS CALIBRATION REQUIREMENT		3% ERROR	.5 ARC-SEC (1σ) USED IN ERROR BUDGETS
DRIRU CALIBRATION REQUIREMENT		3% ERROR	
ATTITUDE DATA PROCESSING REQUIREMENT		1% ERROR	

ADS: ANGULAR DISPLACEMENT SENSOR
DRIRU: DRY ROTOR INERTIAL REFERENCE UNIT
TDRSS: TRACKING AND DATA RELAY SATELLITE SYSTEM

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FIGURE 2-7

TYPICAL TDRSS AND SOLAR ARRAY INDUCED ATTITUDE DEVIATION
(RUNNING 30 SECONDS RMS ABOVE 0.01 Hz)
TDRSS AT 30 DEG.

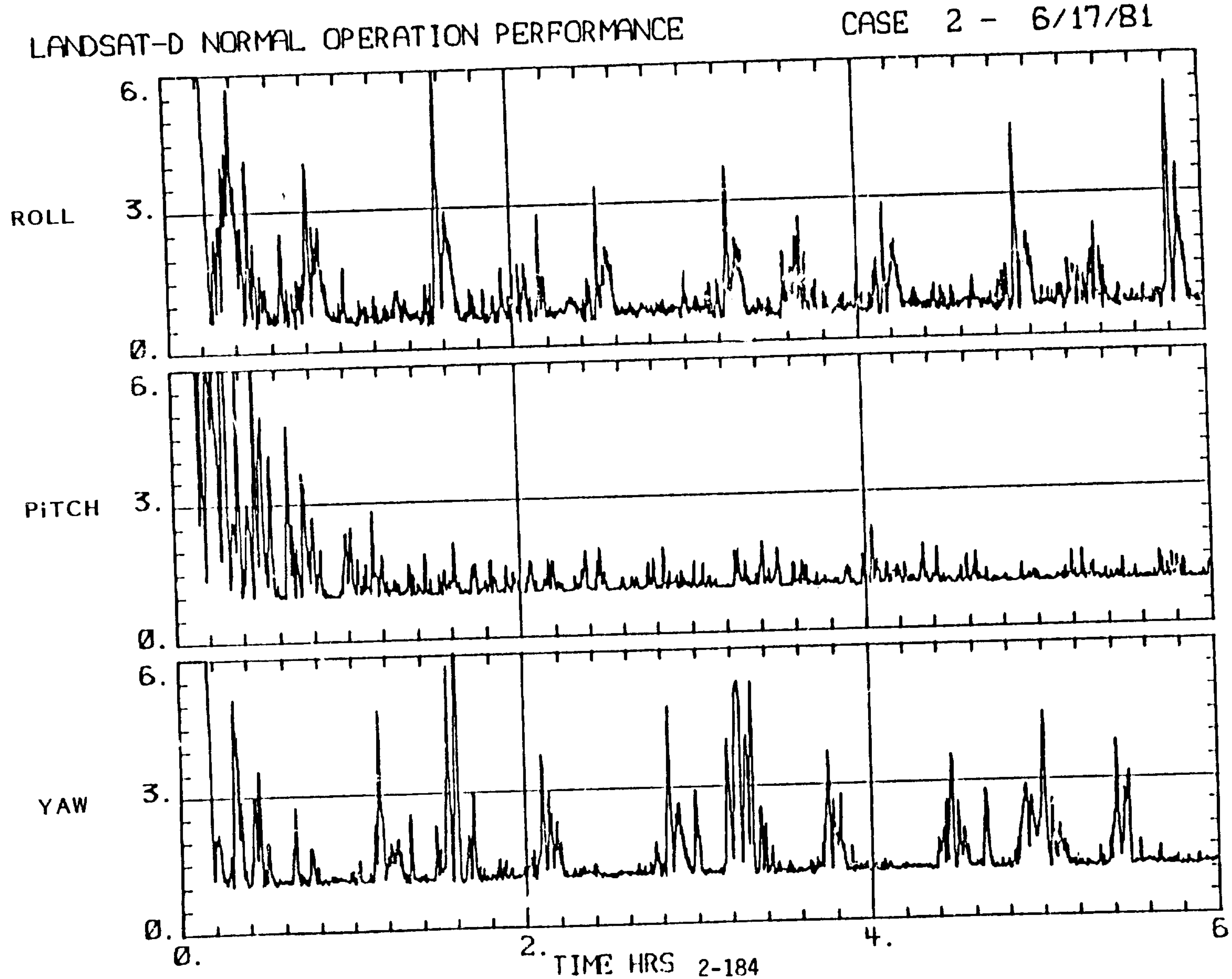
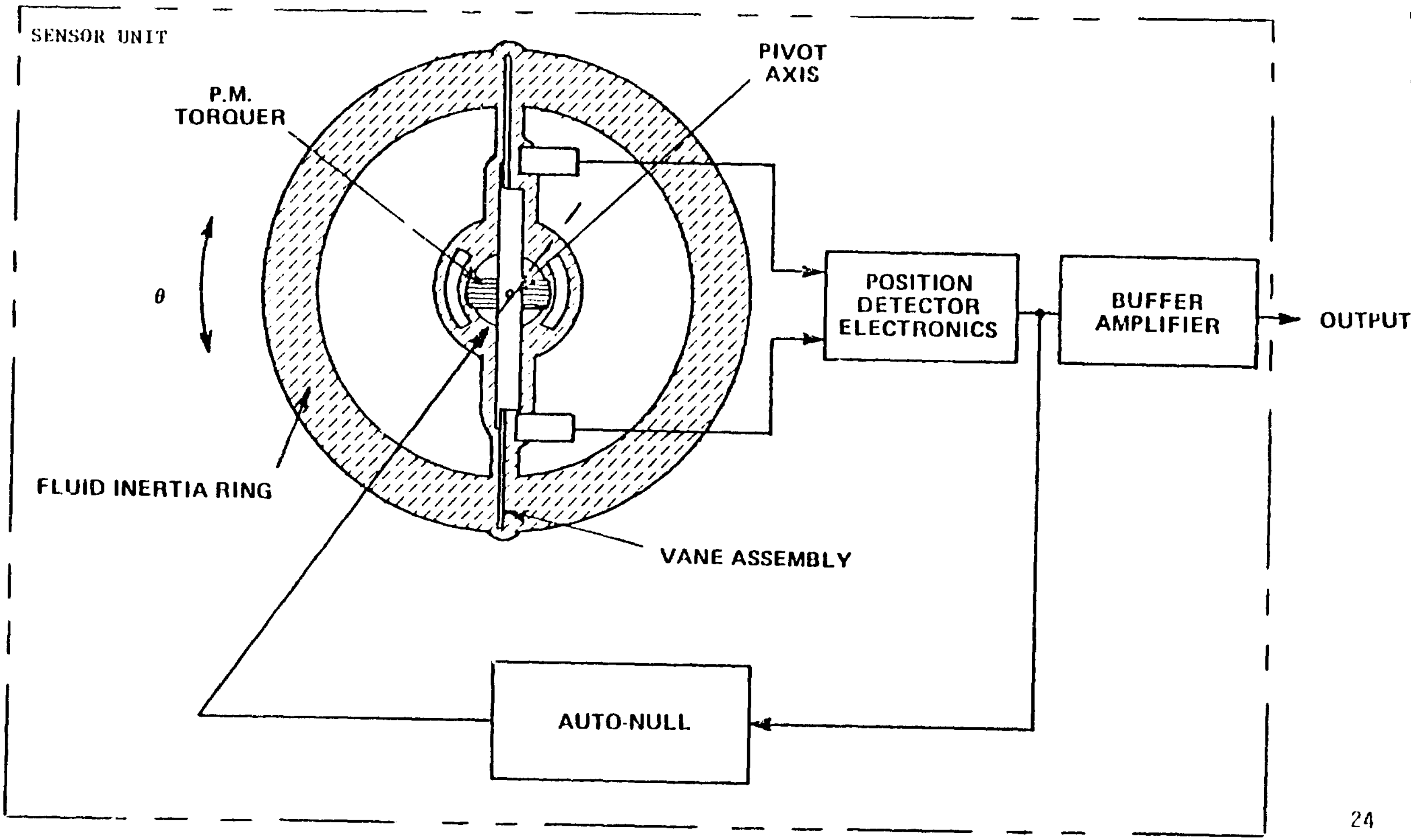


FIGURE 2-8

ANGULAR DISPLACEMENT SENSOR



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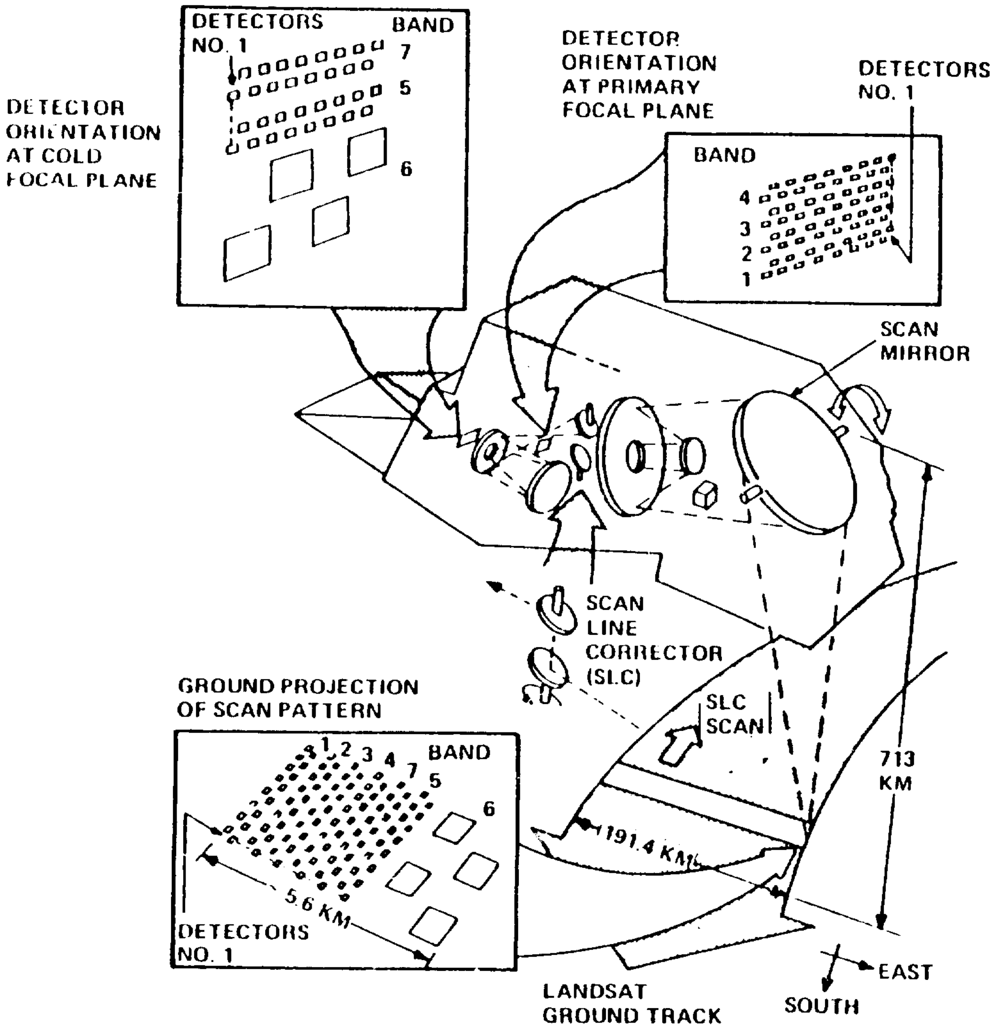
THEMATIC MAPPER

SCAN PATTERN

SCAN PROFILE

FIGURE 2-9

THEMATIC MAPPER GEOMETRY



KEY GEOMETRIC FEATURES

- SCAN MIRROR
  - BI-DIRECTIONAL CROSS TRACK SCANNING
  - DATA AVAILABLE TO GROUND:
    - SCAN START TIME
    - SCAN DIRECTION
    - FIRST HALF SCAN TIME ERROR
    - SECOND HALF SCAN TIME ERROR
- SCAN LINE CORRECTOR
  - PROVIDES IN TRACK SCANNING
- TWO FOCAL PLANE ASSEMBLIES
- INSTANTANEOUS FIELD OF VIEW (IFOV)
  - BANDS 1-5, 7: 42.5 μrad (30 METERS)
  - BAND 6: 170 μrad (120 METERS)

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FIGURE 2-10

DETECTOR PROJECTION AT PRIME FOCAL PLANE

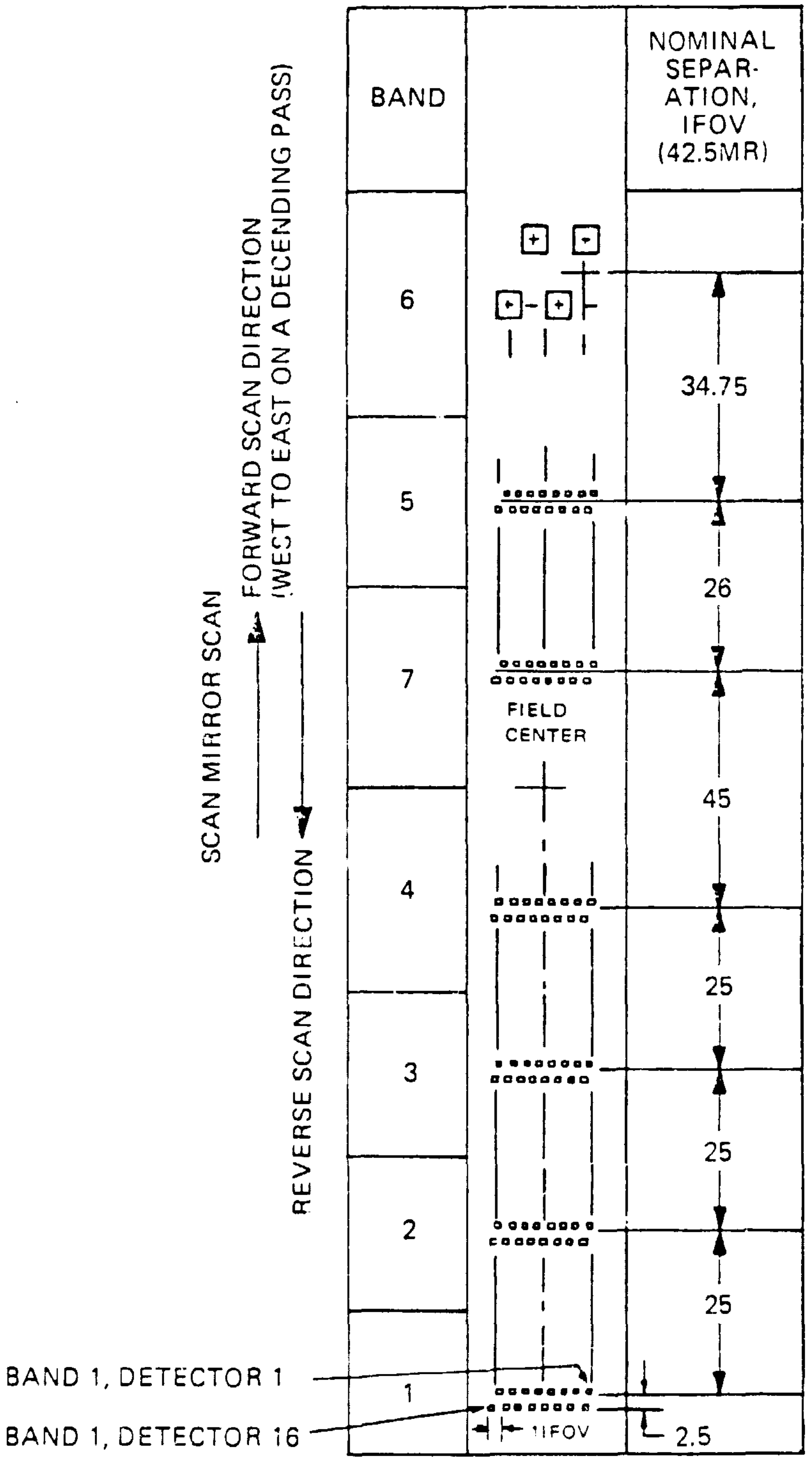

FIGURE 2-11
THEMATIC MAPPER SCANNING

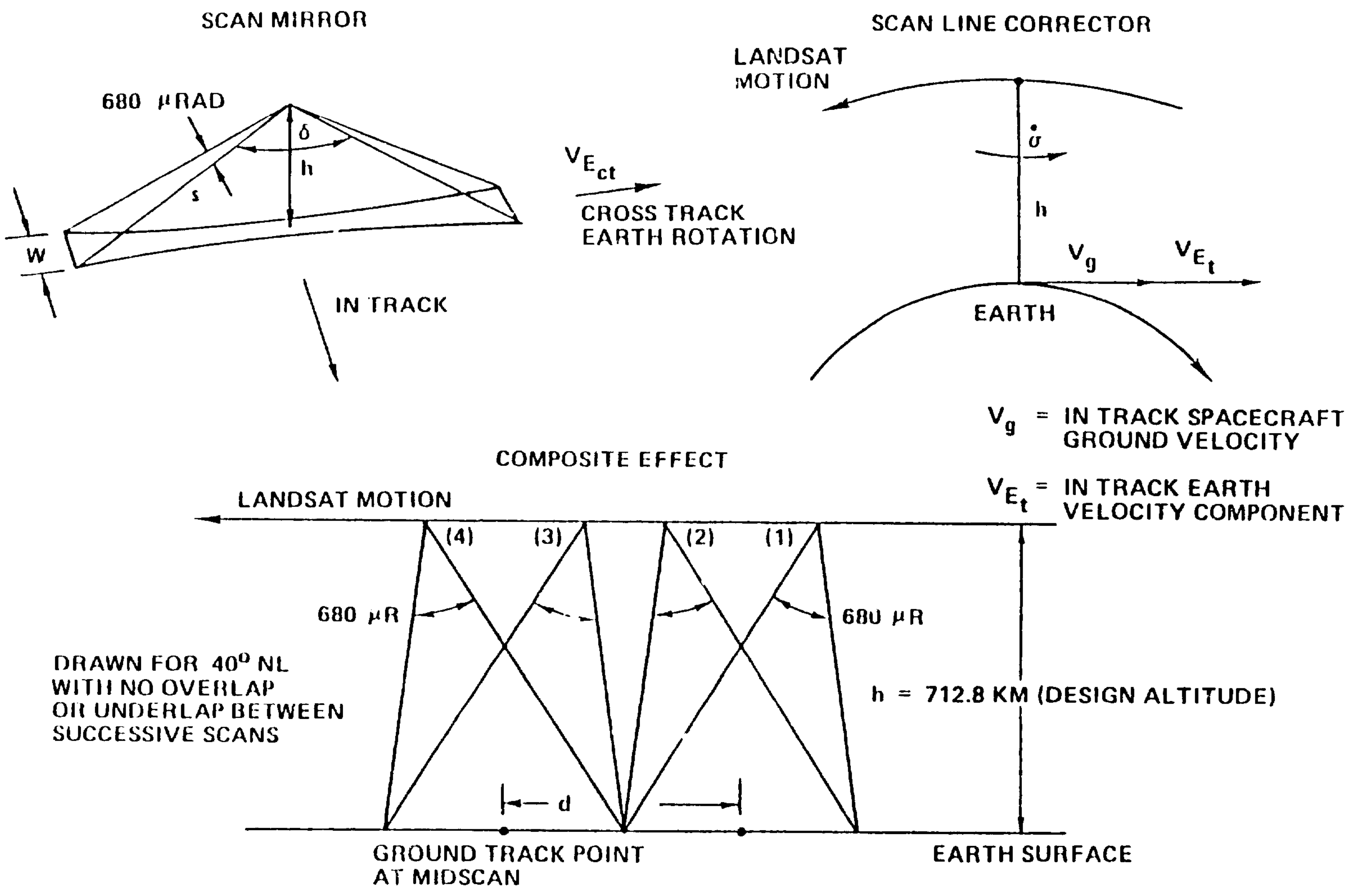

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FIGURE 2-12

THEMATIC MAPPER SCAN
IS AFFECTED BY ALTITUDE DEVIATION

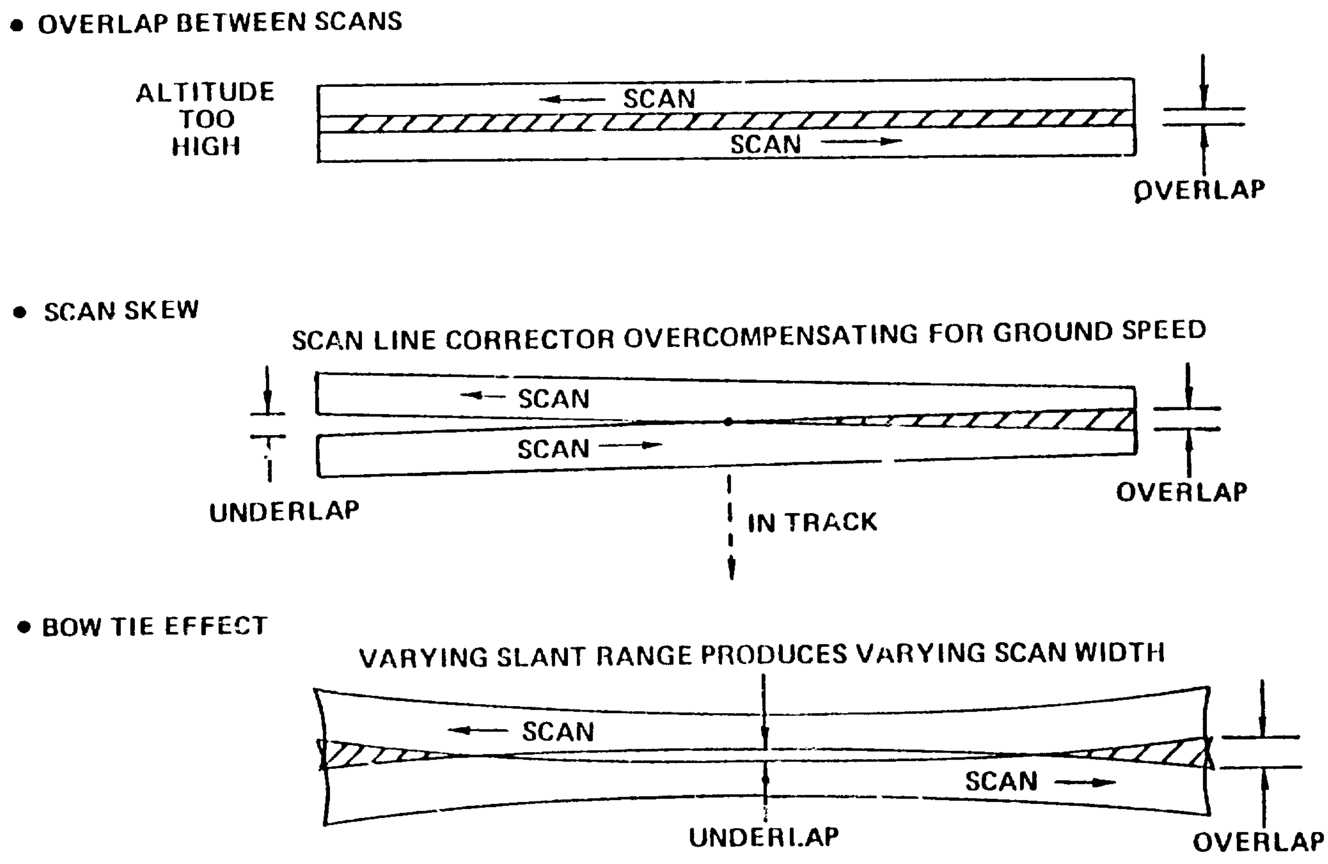

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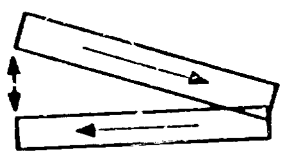
FIGURE 2-13
SCAN GAP** ERROR

ALTITUDE VARIATION	SPACECRAFT ATTITUDE DEVIATION	TM UNDERLAP/OVERLAP
696 – 741 KM FOR 705.3 ORBIT 713 KM TM DESIGN ALTITUDE	LESS THAN 1 PIXEL	0.2 PIXEL (SPEC)

END
SCAN
GAP



EARTH LOCATION	WORST CASE END SCAN GAP IN PIXELS*
NORTHERN HEMISPHERE	-0.7 TO 0.8
45°N	-0.4 TO 0.6
EQUATOR	-0.2 TO 0.8
45°S	-0.9 TO 0.1
SOUTHERN HEMISPHERE	-1.6 TO 0.8

WORST CASE GAP RANGE

-2.8 TO 2.0

(WORST CASE TOTAL OF ALTITUDE VARIATION, JITTER, TM UNDERLAP/OVERLAP EFFECTS)

*INCLUDES SCAN WIDTH, SCAN LINE CORRECTOR SKEW AND BOWTIE EFFECTS

**GAP < 0 : OVERLAP
= 0 : NOMINAL
> 0 : UNDERLAP

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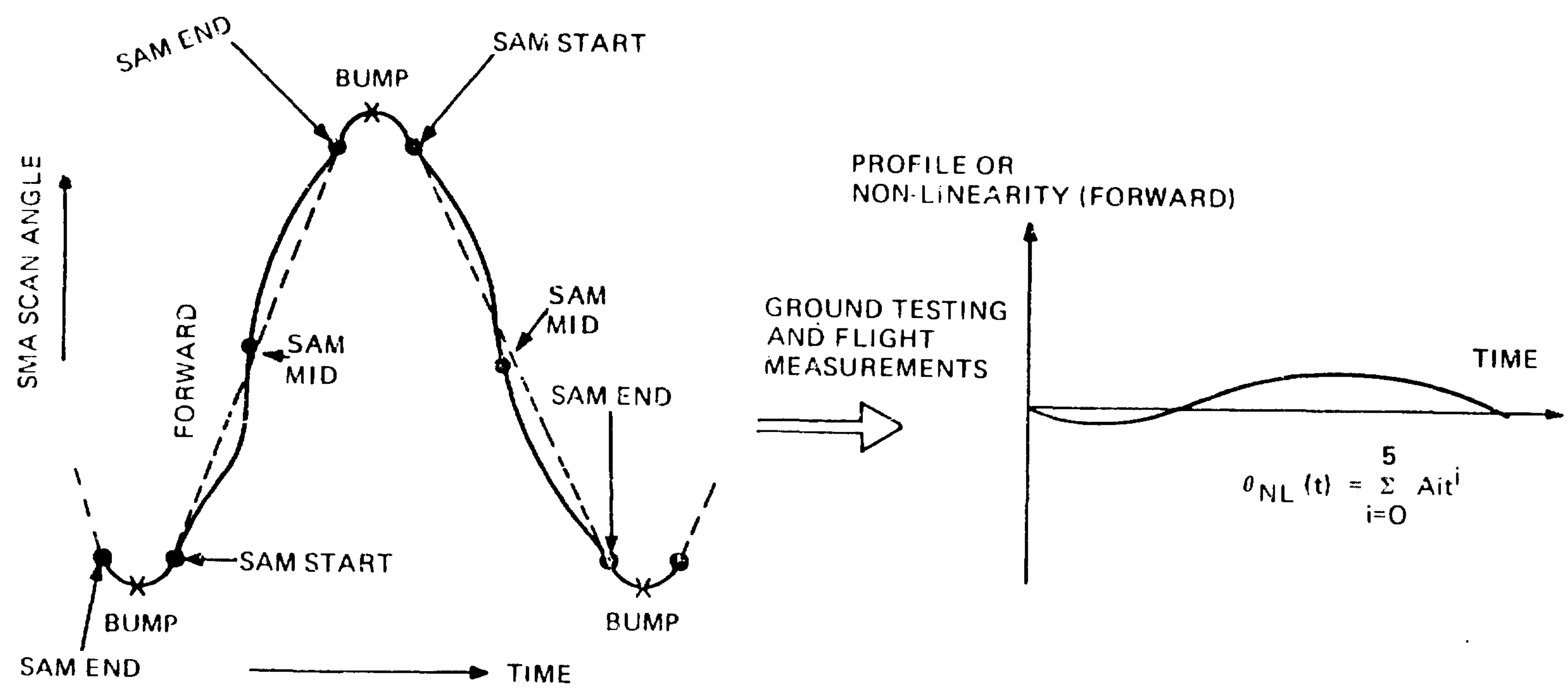
FIGURE 2-14

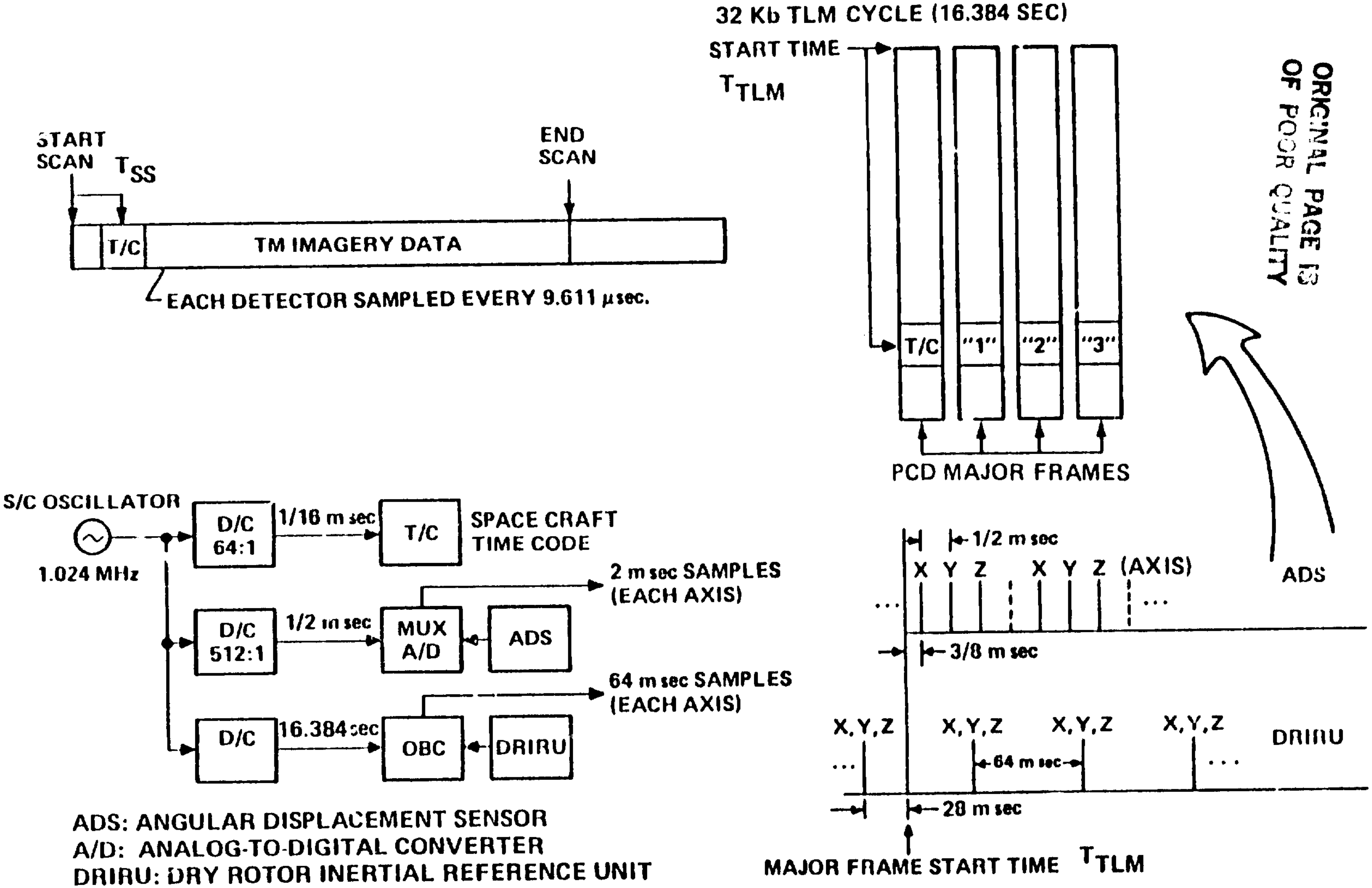
TM SCAN MIRROR PROFILE



SAM: SCAN ANGLE MONITOR

FLIGHT SEGMENT DATA COORDINATION

FIGURE 2-15
ATTITUDE DATA AND SCAN START TIMING



ADS: ANGULAR DISPLACEMENT SENSOR
A/D: ANALOG-TO-DIGITAL CONVERTER
DRIRU: DRY ROTOR INERTIAL REFERENCE UNIT
D/C: DOWN COUNTER
OBC: ON BOARD COMPUTER
T/C: TIME CODE

C-3

TM Geometric Processing — Ground Segment

Eric Beyer

TM IMAGE GROUND PROCESSING

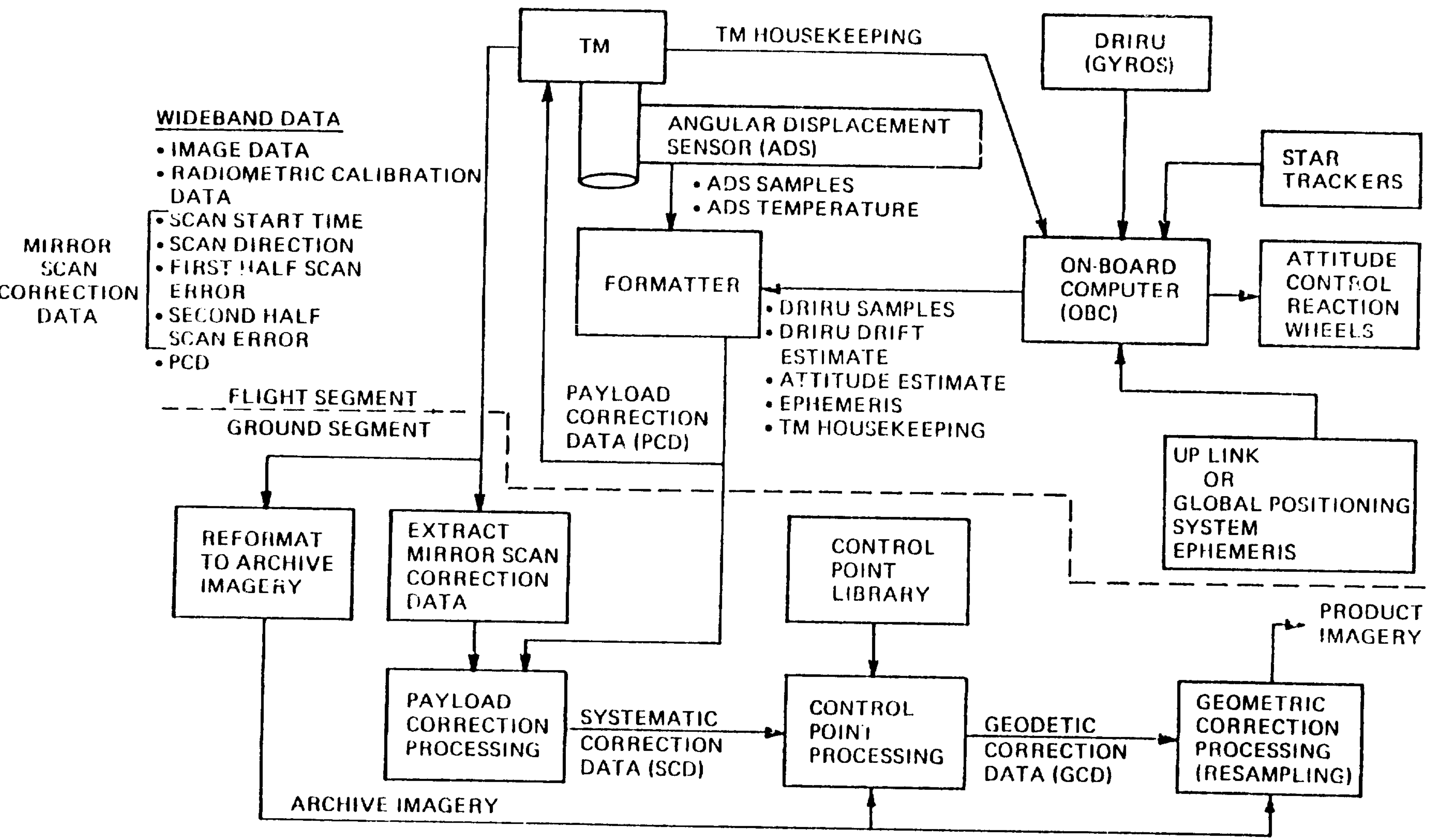
PAYLOAD CORRECTION PROCESSING

CONTROL POINT PROCESSING

GEOMETRIC CORRECTION PROCESSING

FIGURE 1-4

LANDSAT D TM GEOMETRIC CORRECTION SYSTEM OVERVIEW



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SYSTEMATIC CORRECTION DATA

PURPOSE: PROVIDES MEANS TO LOCATE IMAGE DATA ON OUTPUT COORDINATES

BENCHMARK MATRIX

A 2-DIMENSIONAL GRID OF TM FOCAL PLANE BENCHMARKS ON OUTPUT COORDINATES. COMPUTED ASSUMING PERFECT POINTING AND MIRROR PROFILES.

HIGH FREQUENCY MATRICES (ALONG- AND CROSS-SCAN)

CORRECTS BENCHMARKS FOR ATTITUDE DEVIATIONS AND MIRROR PROFILE NON-LINEARITIES.

FOCAL PLANE GEOMETRY MATRICES

CORRECTS BENCHMARKS FOR DETECTOR POSITION RELATIVE TO FOCAL PLANE OPTICAL AXIS.

PROCESSING PARAMETERS

NEEDED FOR THE RESAMPLING PROCESS

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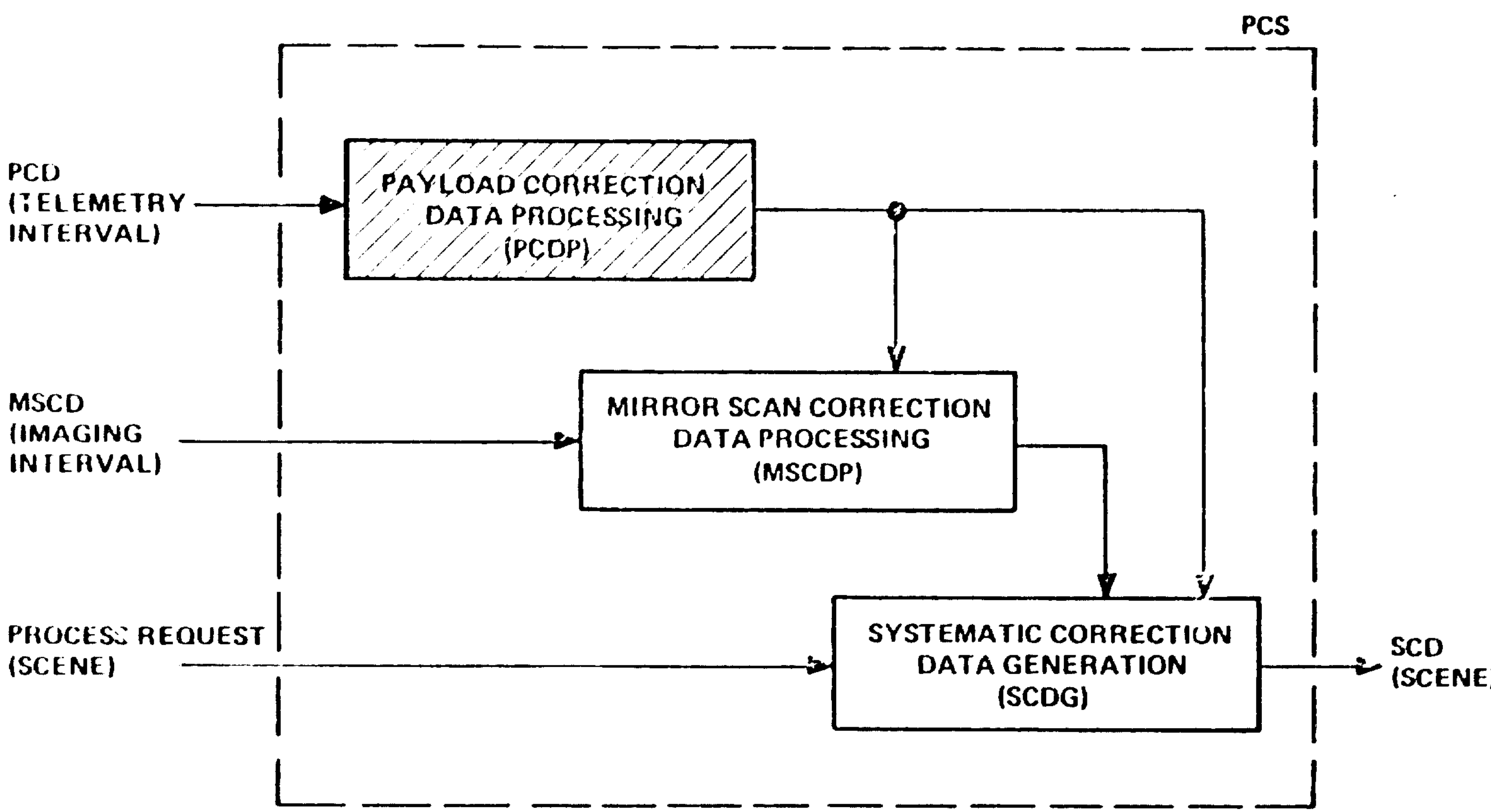
PAYLOAD CORRECTION PROCESSING



MSCD: MIRROR SCAN CORRECTION DATA
PCD: PAYLOAD CORRECTION DATA
SCD: SYSTEMATIC CORRECTION DATA

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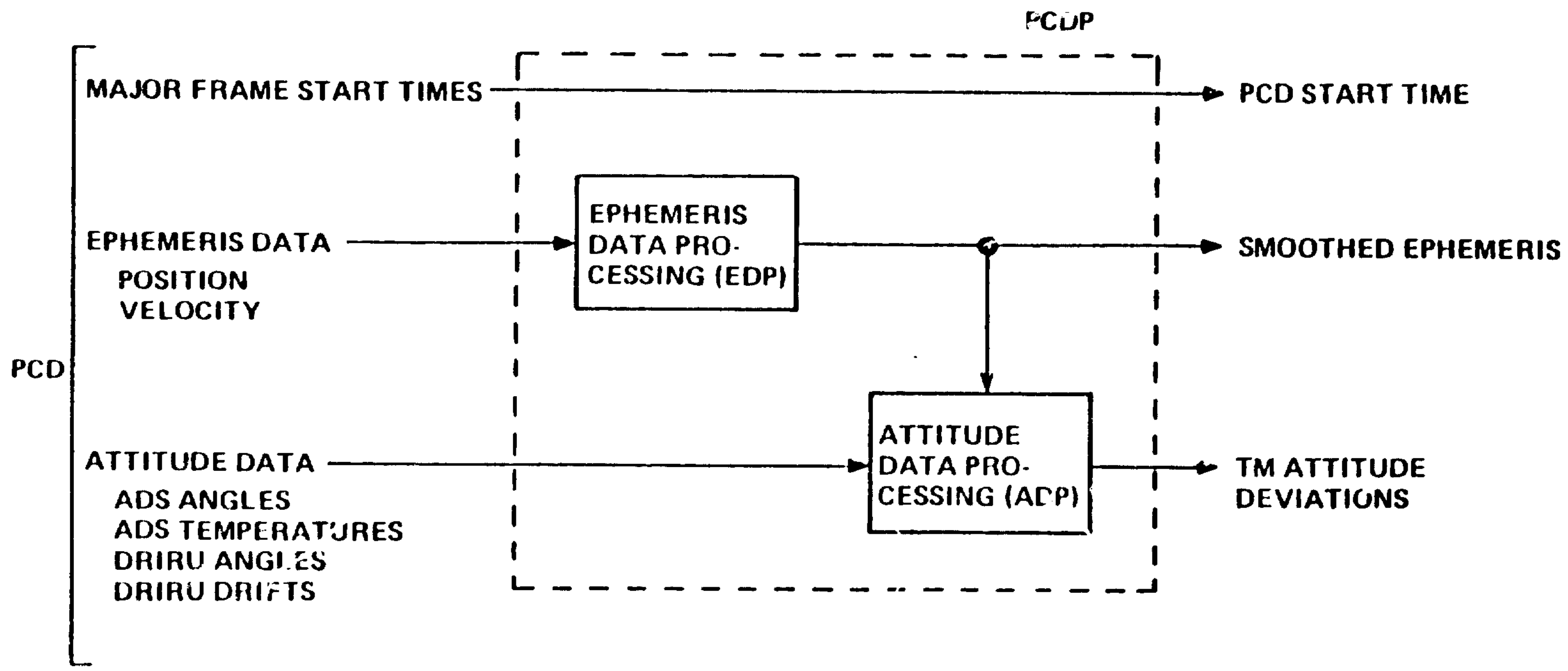
PAYLOAD CORRECTION DATA PROCESSING



ADS: ANGULAR DISPLACEMENT SENSOR
DRIRU: DRY ROTOR INERTIAL REFERENCE UNIT
PCD: PAYLOAD CORRECTION DATA

EPHEMERIS DATA PROCESSING

- PROVIDES EPHEMERIS WITH KNOWN ERROR DYNAMICS FOR CONTROL POINT PROCESSING

$$\underset{T = 8.192\ \mathrm{SEC}}{\bar{X}, \dot{\bar{X}}\ (\mathrm{ECI})} \longrightarrow \boxed{\mathrm{EDP}} \longrightarrow \underset{T = 2.048\ \mathrm{SEC}}{\bar{X}, \dot{\bar{X}}\ (\mathrm{ECI})}$$

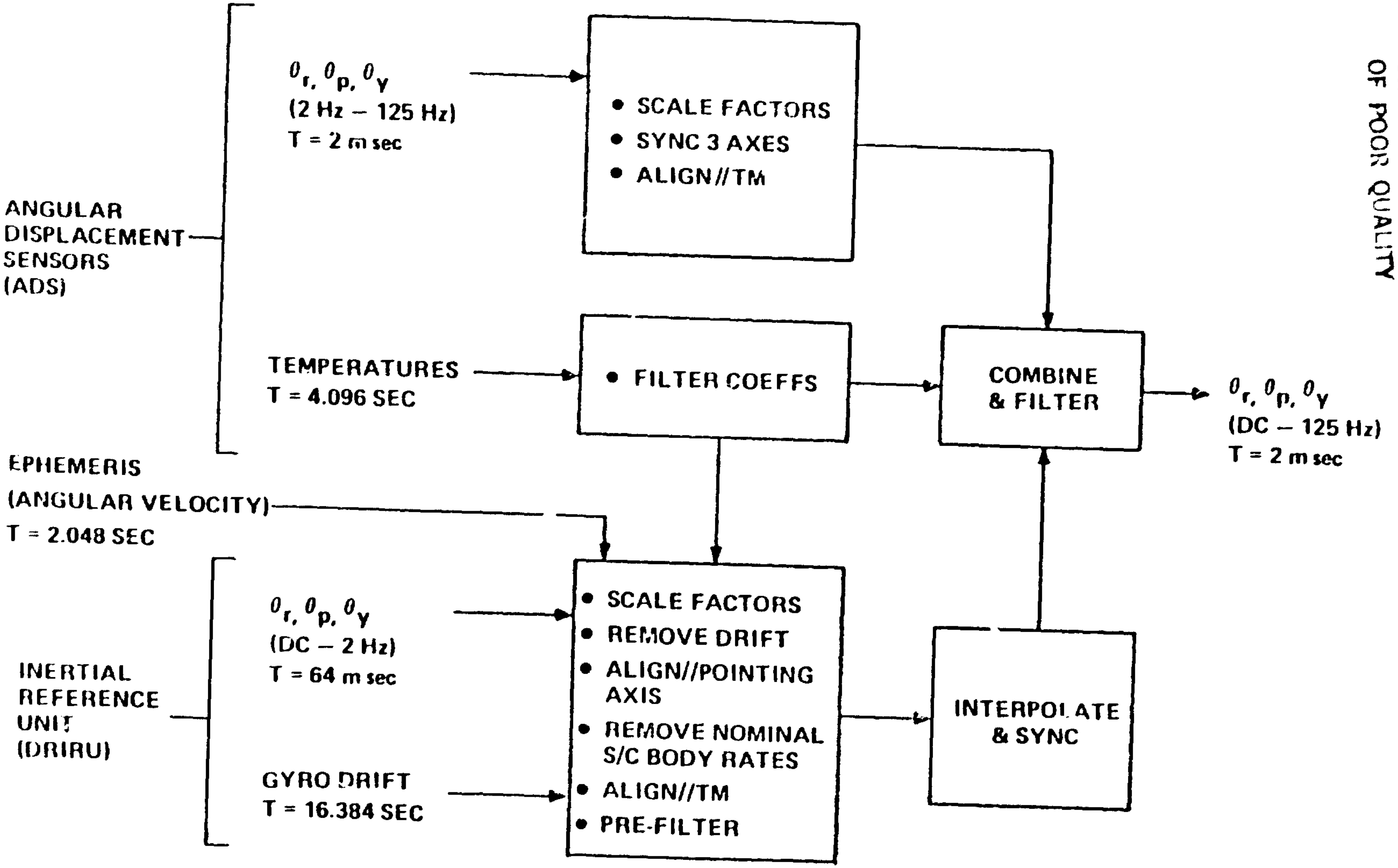
FUNCTIONS

- SMOOTH (GPS AND OBC DISCONTINUITIES)
- ELIMINATE BAD DATA (TELEMETRY TRANSMISSION ERRORS)
- INTERPOLATE
- SYNCHRONIZE WITH TELEMETRY MAJOR FRAME START TIME

ECI: EARTH-CENTERED INERTIAL COORDINATES
GPS: GLOBAL POSITIONING SYSTEM
OBC: ON-BOARD COMPUTER

FIGURE 3-2

ATTITUDE DATA PROCESSING



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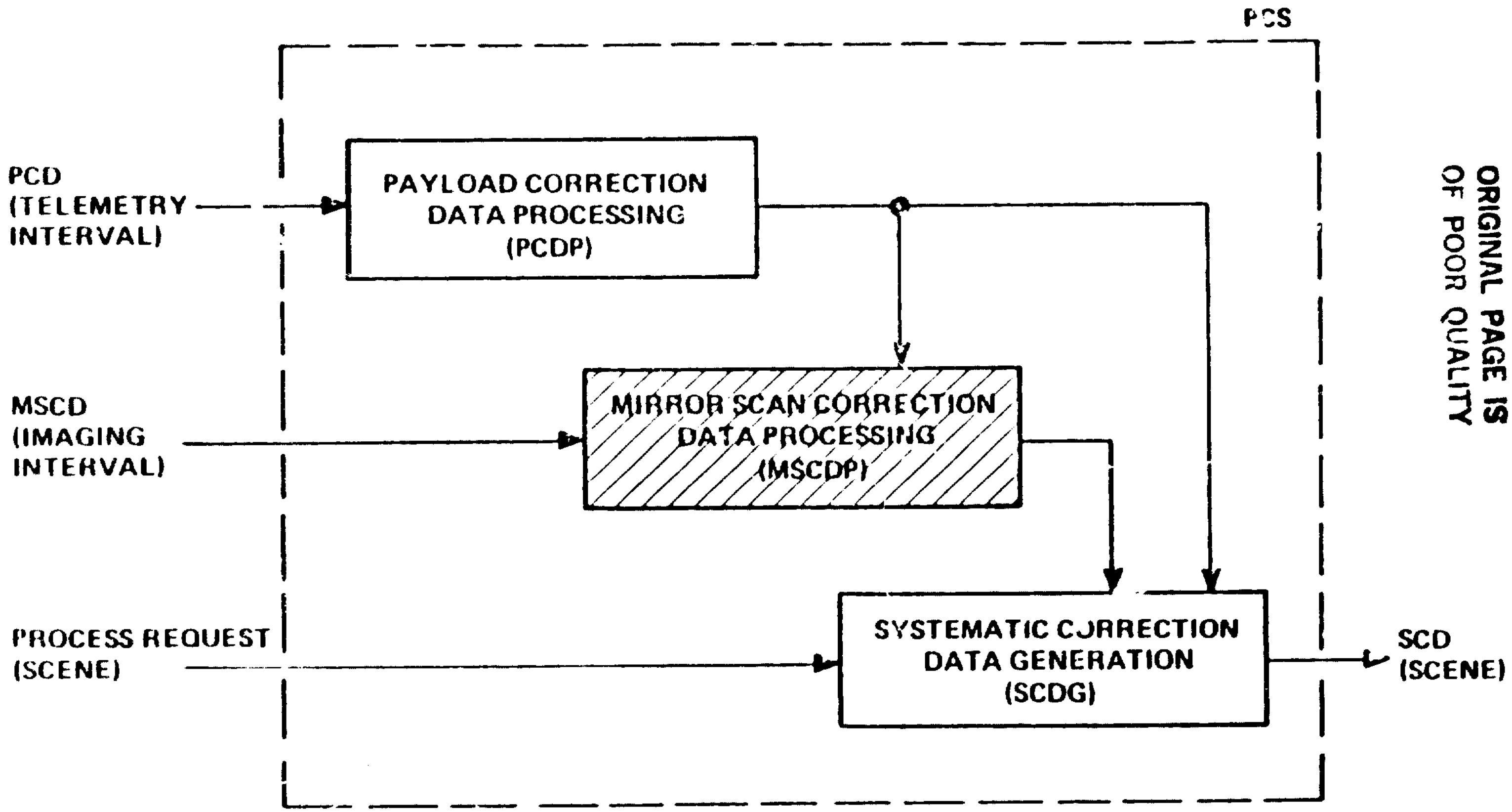
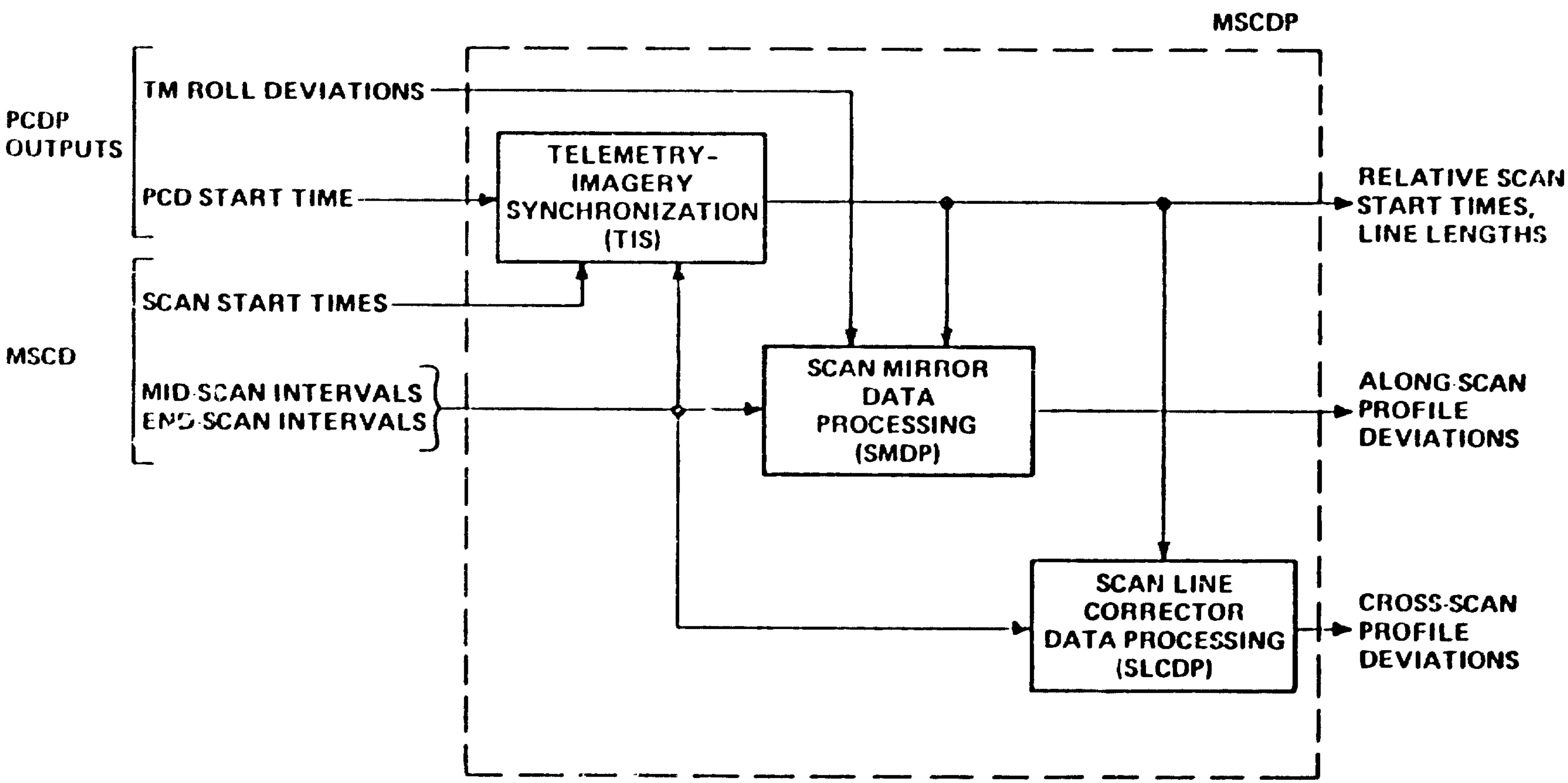
PAYLOAD CORRECTION PROCESSING



MSCD: MIRROR SCAN CORRECTION DATA
PCD: PAYLOAD CORRECTION DATA
SCD: SYSTEMATIC CORRECTION DATA

FIGURE 3-3

MIRROR SCAN CORRECTION DATA PROCESSING



PCDP: PAYLOAD CORRECTION DATA PROCESSING
MSCD: MIRROR SCAN CORRECTION DATA PROCESSING

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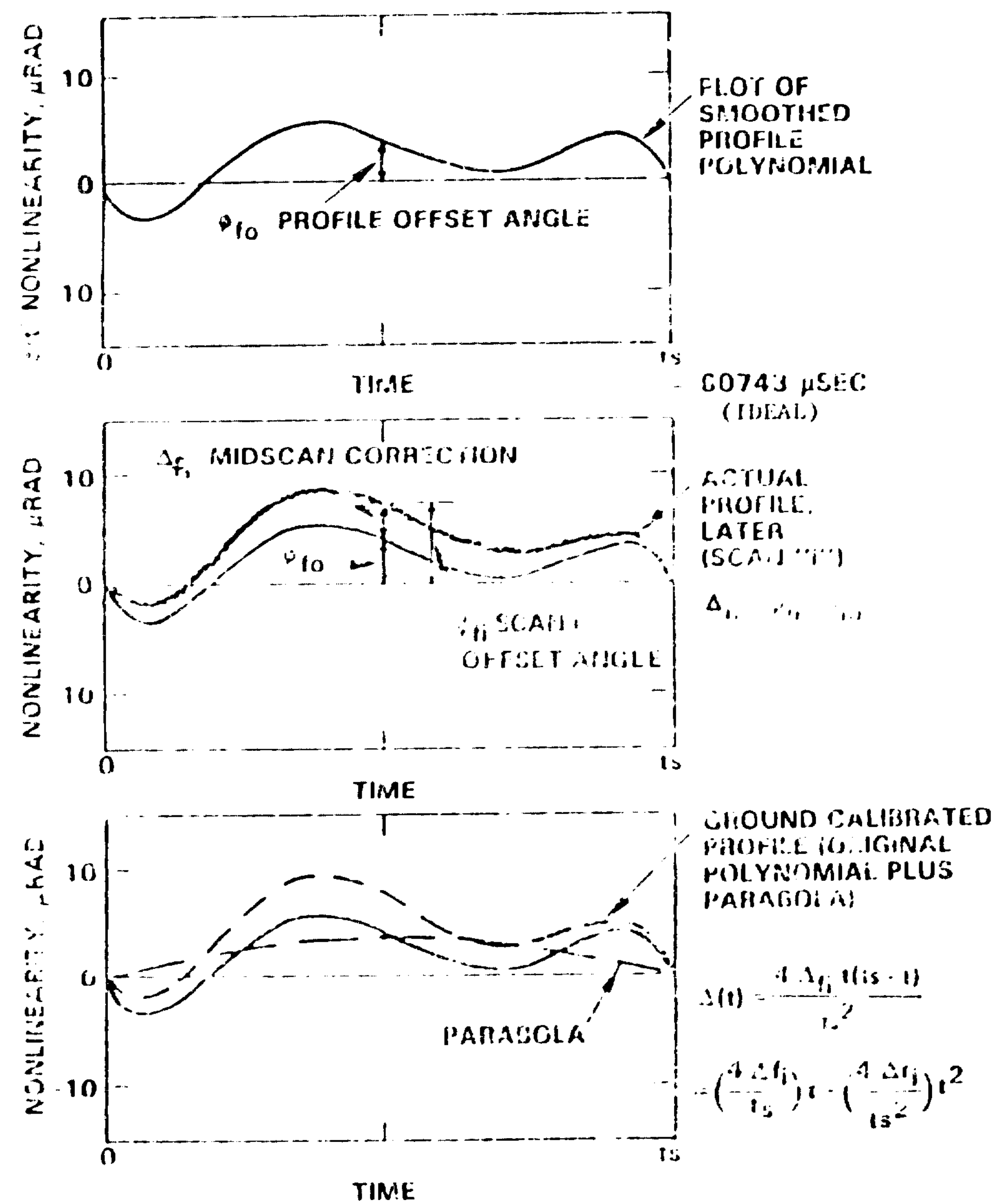
TM MID SCAN CORRECTION



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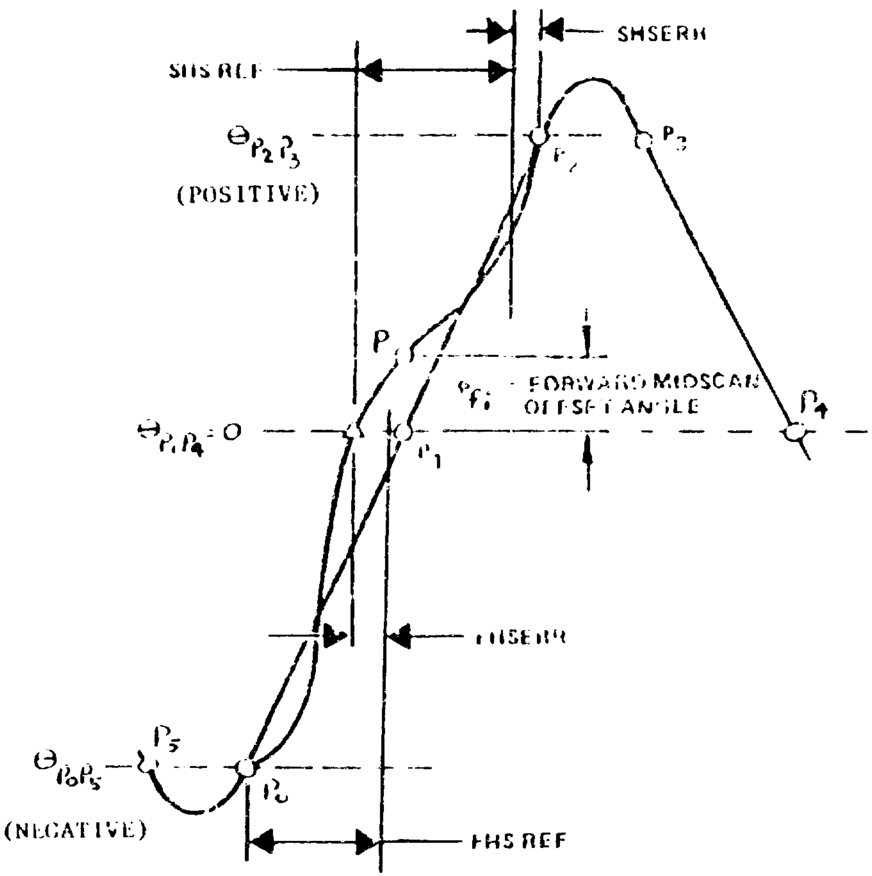
FORWARD SCAN OFFSET ANGLE ϕ_{fi}



TAKING INTO ACCOUNT ACTIVE SCAN TIME (T_S) AND SAM WING MIRROR RATIO (K_0'):

$$\phi_{fi} = (T_1(K_0' - 1) + T_2(K_0'))\left(\frac{\theta_{P_2P_3} - \theta_{P_0P_5}}{T_S}\right)$$

$$K_0' = \frac{-\theta_{P_0P_5}}{\theta_{P_2P_3} - \theta_{P_0P_5}}$$

T_1 = FHS REF - FHSERR

T_2 = SHS REF - SHSERR

$T_S = T_1 + T_2$

<u>FORWARD MIDSCAN CORRECTION, SCAN i</u>

$$\Delta_{fi} = \phi_{fi} - \phi_{fa}$$

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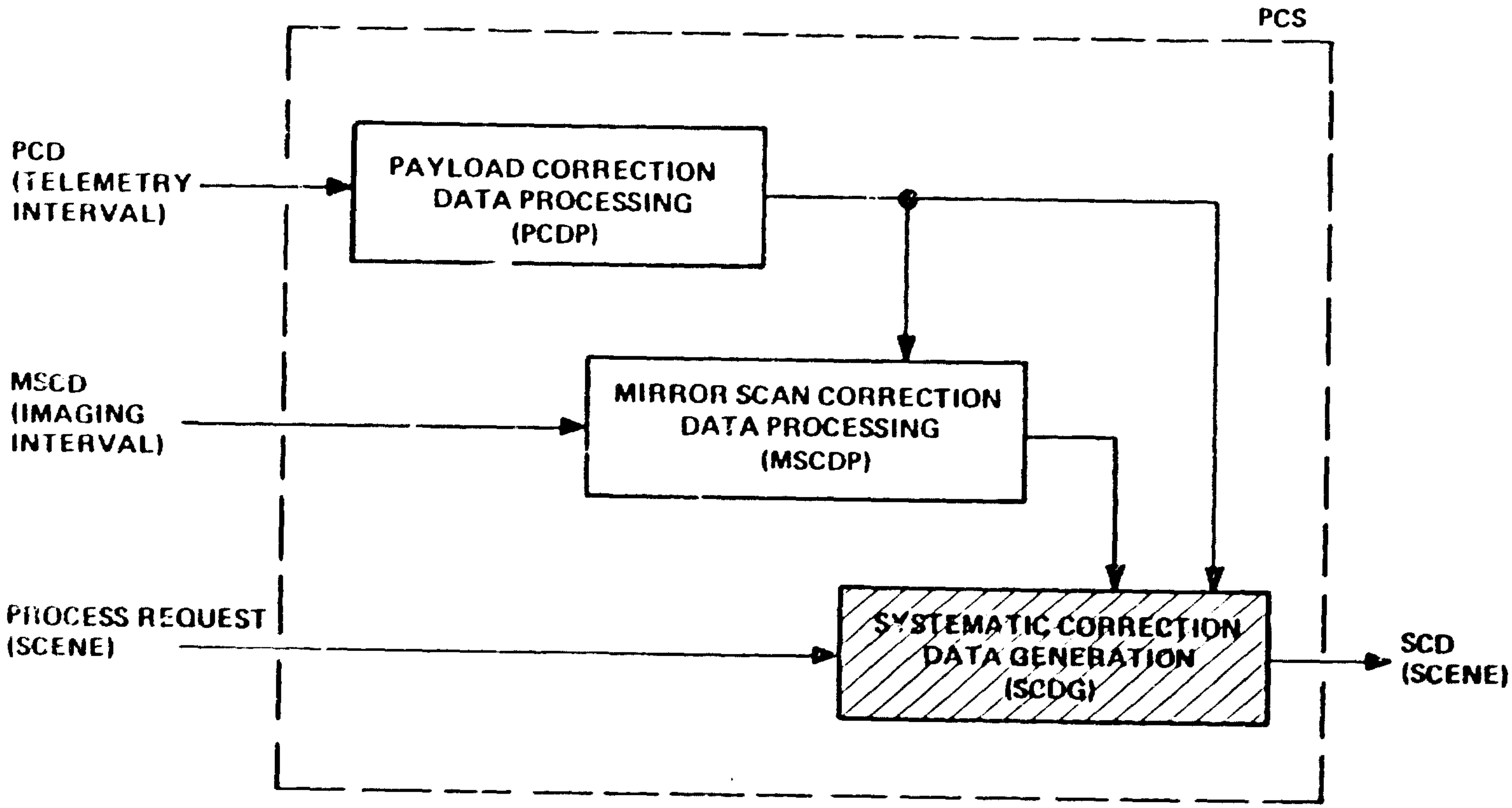
PAYLOAD CORRECTION PROCESSING



MSCD: MIRROR SCAN CORRECTION DATA
PCD: PAYLOAD CORRECTION DATA
SCD: SYSTEMATIC CORRECTION DATA

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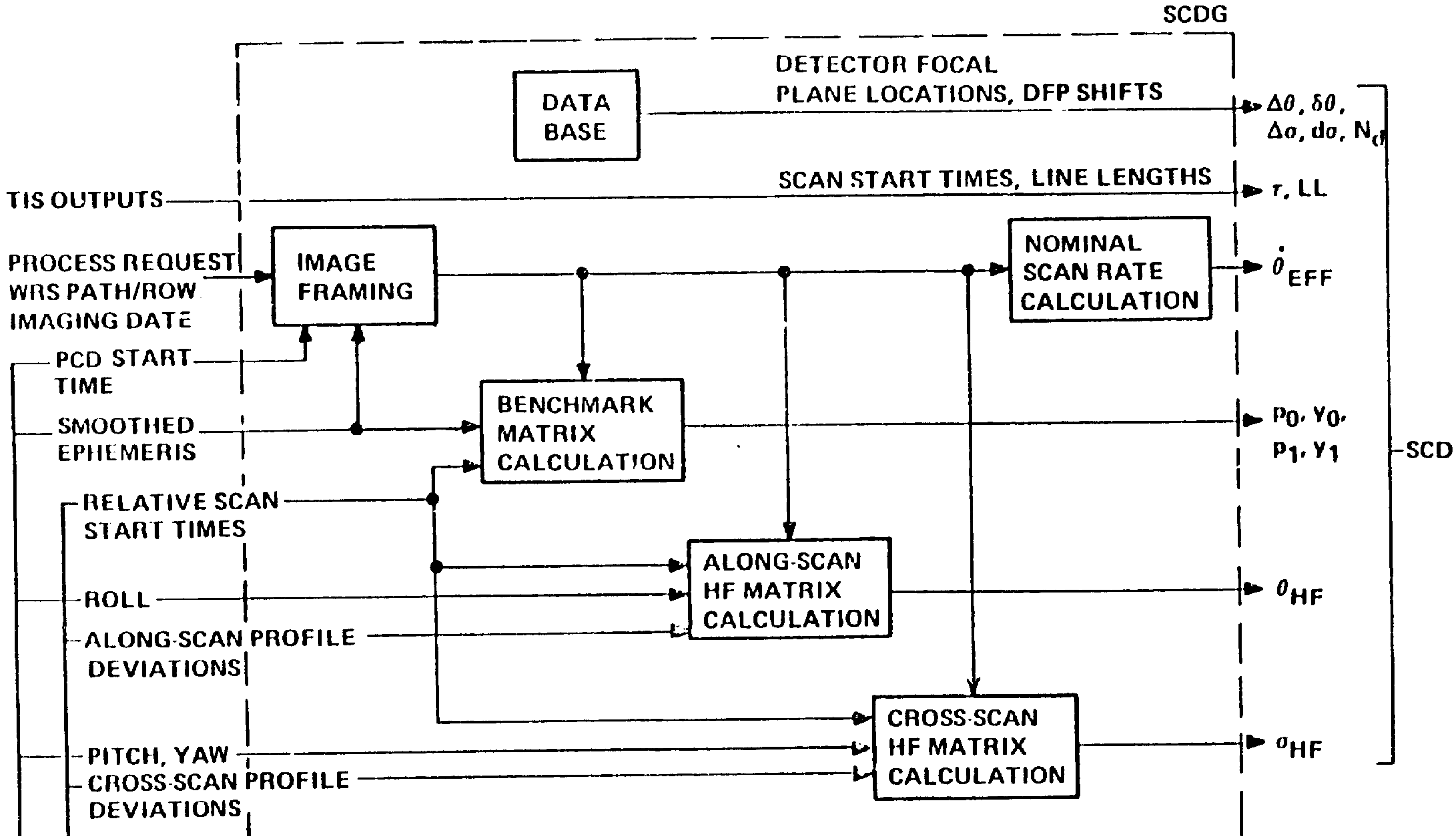
FIGURE 3-4
SYSTEMATIC CORRECTION DATA GENERATION

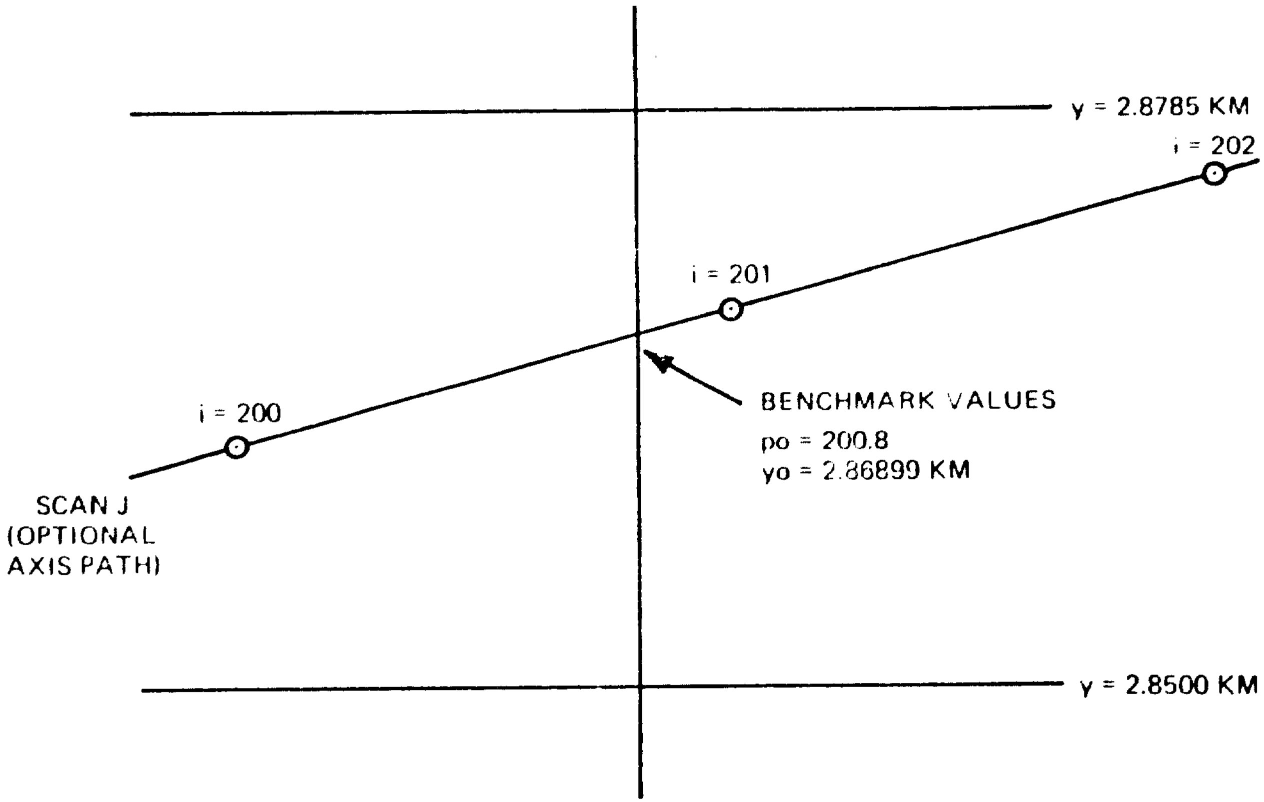


TIS: TELEMETRY-IMAGERY SYNCHRONIZATION
DFP: DATA FORMATTER-PROCESSOR
WRS: WORLD REFERENCE SYSTEM
HF: HIGH FREQUENCY

TLM: TELEMETRY
MSCDP: MIRROR SCAN CORRECTION DATA PROCESSING
PCDP: PAYLOAD CORRECTION DATA PROCESSING

FIGURE 3-8

BENCHMARK MATRIX CONCEPT
(AN EXAMPLE)



X, Y : OUTPUT COORDINATE SYSTEM
i : SAMPLE NUMBER OF ODD DETECTORS RELATIVE TO SCAN START

BENCHMARK MATRIX CALCULATION

INPUT

- SCENE CENTER PARAMETERS
- TM-TO-POINTING AXIS ALIGNMENT
- EPHEMERIS DATA
- SCAN-START TIME DATA

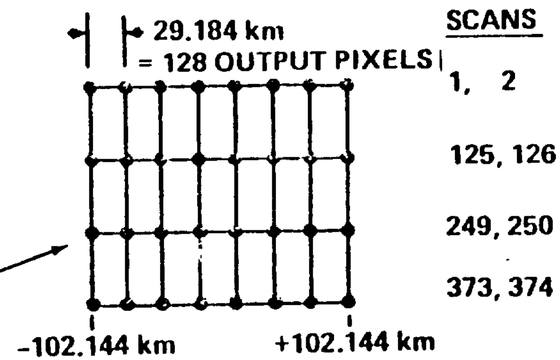
ASSUMPTIONS

- PERFECT POINTING
- LINEAR MIRROR PROFILES

OUTPUT

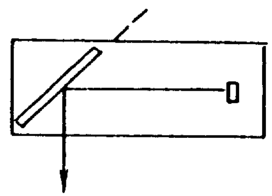
- p_0, y_0 – OPTICAL AXIS ORIGIN
- p_1, y_1 – CROSS-SCAN OFFSET

AT 64 POINTS



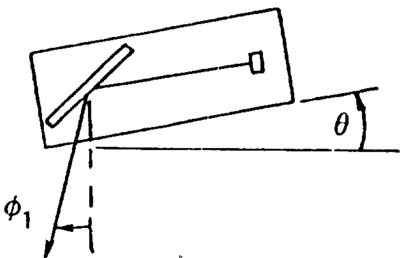
TM FRAME MOTION AND MIRROR
MOTION EFFECTS

1
START



2
MIRROR STATIONARY,
ROTATE FRAME

$\phi_1 = -\theta$



3
FRAME STATIONARY,
ROTATE MIRROR

$\phi_T = 2\psi - \theta$

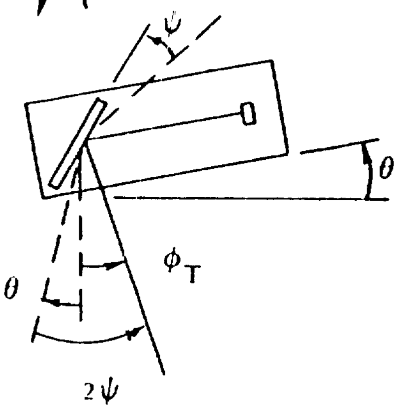
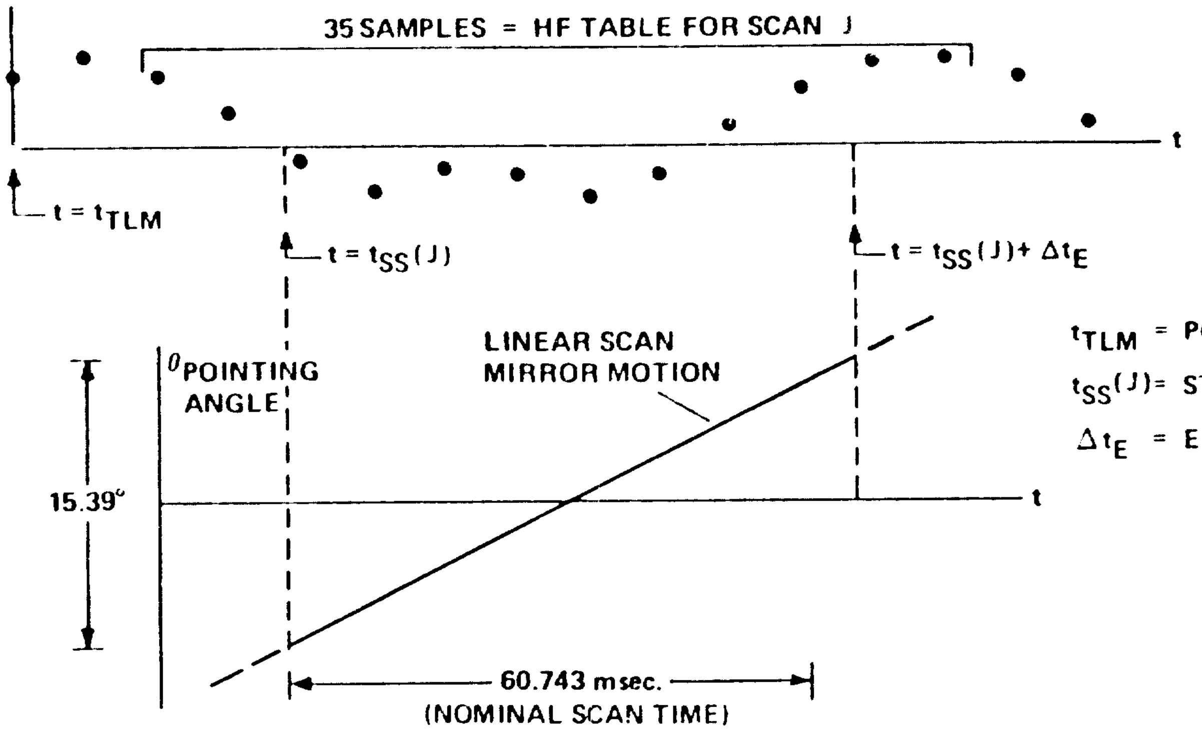


FIGURE 3-9
ALONG SCAN HIGH-FREQUENCY MATRICES



t_{TLM} = PCD TELEMETRY START TIME

$t_{SS}(J)$ = START SCAN TIME, SCAN J

Δt_E = END SCAN TIME INTERVAL

ALONG-SCAN $\theta_{HF} = \theta_\epsilon + \theta_{ROLL}$; θ_ϵ = SCAN MIRROR NONLINEARITY

HF: HIGH FREQUENCY

FIGURE 3-5

SCD: OPTICAL AXIS POSITION ON THE OUTPUT COORDINATE SYSTEM

BENCHMARK MATRICES

$p_0(i,j,k)$, $\gamma_0(i,j,k)$

$p_1(i,j,k)$, $\gamma_1(i,j,k)$

i = x coordinate index = 1, . . . ,8

j = sweep index = 1, . . . ,4

k = scan direction index = 1,2

INCLUDES: EPHEMERIS, NOMINAL LINEAR TM ACTIVE SCAN, PERFECT ACS, KNOWN INSTRUMENT ALIGNMENT, MAP PROJECTION

(ONE SET FOR EACH PROJECTION)

ALONG SCAN

HIGH FREQUENCY MATRIX

$\theta_{HF}(i,j)$

i = sample number index = 1, . . . ,35

j = scan number = 1, . . . ,374

INCLUDES: SMA ALONG SCAN PROFILE, SMA LINE LENGTH, S/C ROLL JITTER

MIRROR SCAN START TIMES

$\tau(j)$

j = scan number = 1, . . ., 374

RELATIVE START TIME FOR EACH SCAN

CROSS SCAN

HIGH FREQUENCY MATRIX

$\sigma_{HF}(i,j)$

i = sample number index = 1, . . . ,35

j = scan number = 1, . . . ,374

INCLUDES: SMA CROSS SCAN PROFILE, SMA LINE LENGTH, SLC PROFILE, SLC DELAY, S/C PITCH AND YAW JITTER

SMA: SCAN MIRROR ASSEMBLY
SLC: SCAN LINE CORRECTOR
S/C: SPACECRAFT

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FIGURE 3-6

SCD: OPTICAL AXIS TO DETECTOR SAMPLE LOCATION

NOMINAL POINTING VECTOR SCAN RATE ACROSS OUTPUT COORDINATES

$\dot{\theta}_{EFF}^{(k)}$

k = scan direction index = 1,2

NOMINAL ALONG SCAN FOCAL PLANE BAND LOCATION

$\Delta\theta$ (m)

m = band number = 1, . . . ,7

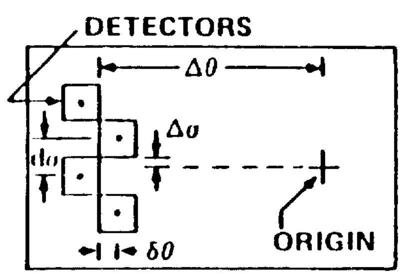
ALONG SCAN ANGULAR DISTANCE FROM OPTICAL AXIS TO BAND CENTER

NOMINAL CROSS-SCAN FOCAL PLANE BAND LOCATION

$\Delta\sigma$ (m)

m = band number = 1, . . . ,7

CROSS SCAN ANGULAR DISTANCE FROM OPTICAL AXIS TO BAND CENTER



TM FOCAL PLANE

SAM: SCAN ANGLE MONITOR

ALONG SCAN FOCAL PLANE DETECTOR LOCATIONS

$\delta\theta$ (m,n,k)

m = band number = 1, . . . ,7
n = detector number = 1, . . . ,16
k = scan direction index = 1,2

INCLUDES: ALONG SCAN ANGULAR DISTANCE BETWEEN BAND CENTER AND DETECTOR LOCATION, DETECTOR CHANNEL DELAYS, SAM PULSE DELAYS

CROSS SCAN FOCAL PLANE DETECTOR SPACING

$d\sigma$ (m)

m = band number = 1, . . . ,7

AVERAGE INTER-DETECTOR CROSS SCAN FOCAL PLANE SPACING

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FIGURE 3-7

SCD: PROCESSING PARAMETERS

SCAN LINE LENGTH	DATA FORMATTER – PROCESSOR ODD DETECTOR SAMPLE SHIFTS
LL (j)	N_d (m,k)
j = scan number = 1, . . . ,374	m = band number = 1, . . . ,7
	k = scan direction index = 1,2
NUMBER OF COMPLETE IMAGING MINOR FRAMES	LINE SHIFT INTRODUCED BY THE DFP FOR ODD NUMBERED DETECTORS

GEOMETRIC ERROR IN SYSTEMATIC CORRECTION DATA (APPROXIMATE)

ERROR SOURCE	CROSS TRACK (METERS 1σ)	ALONG TRACK (METERS 1σ)
EPHEMERIS	100	500
TIME		80
ATTITUDE	123	123
ALIGNMENT	427*	855*
TOTAL (ROOT-SUM-SQUARE)	455 (25 PIXELS 90%)	1001 (55 PIXELS 90%)

*SUBSTANTIAL REDUCTION WILL OCCUR AFTER POST LAUNCH CALIBRATION

CONTROL POINT PROCESSING

- PURPOSE
  - REMOVE BIAS AND DRIFT ERROR EFFECTS FROM SCD
    - ·· EPHEMERIS
    - ·· TIME
    - ·· LOW FREQUENCY ATTITUDE
    - ·· ALIGNMENT

FIGURE 3-10
CONTROL POINT CONCEPT

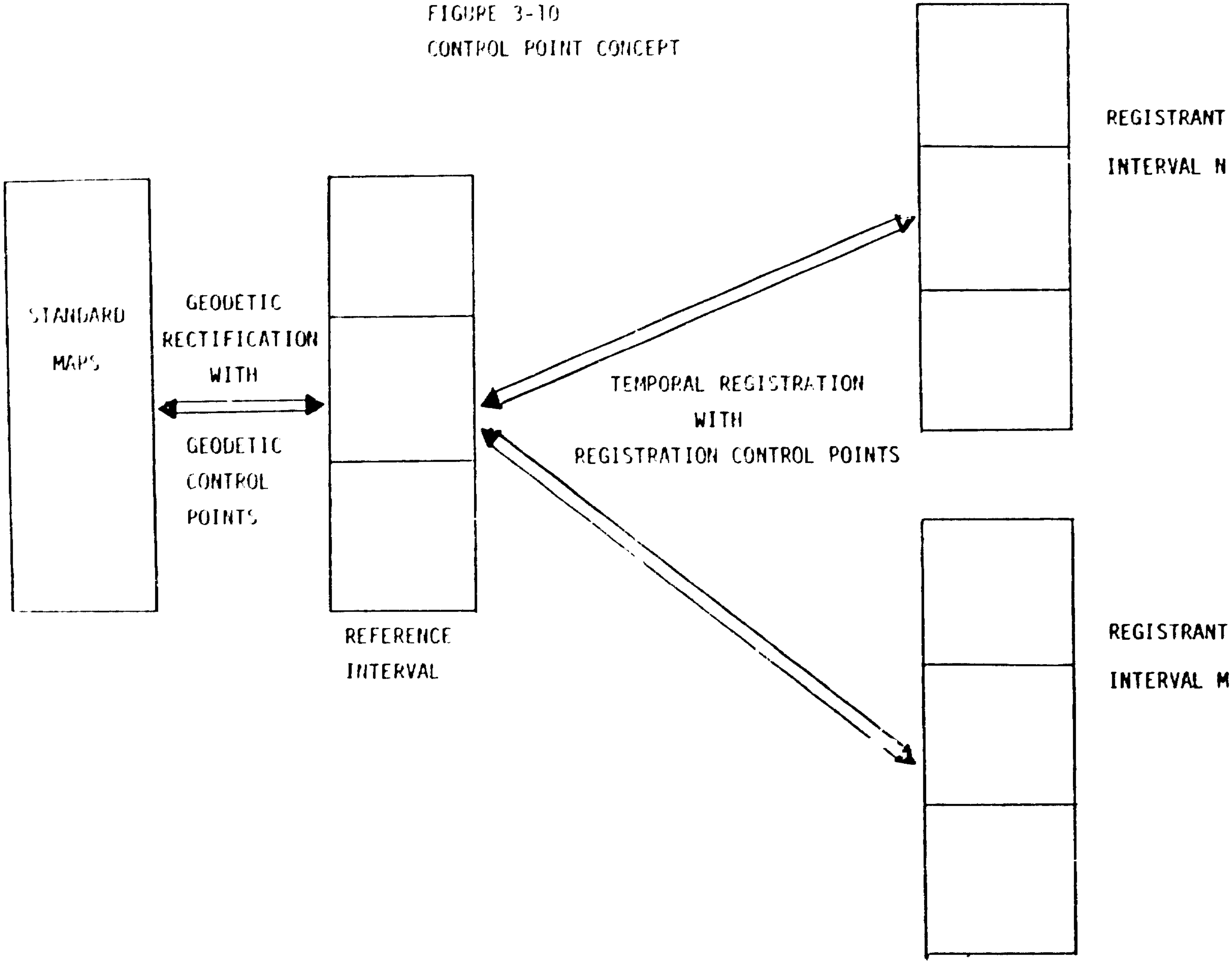

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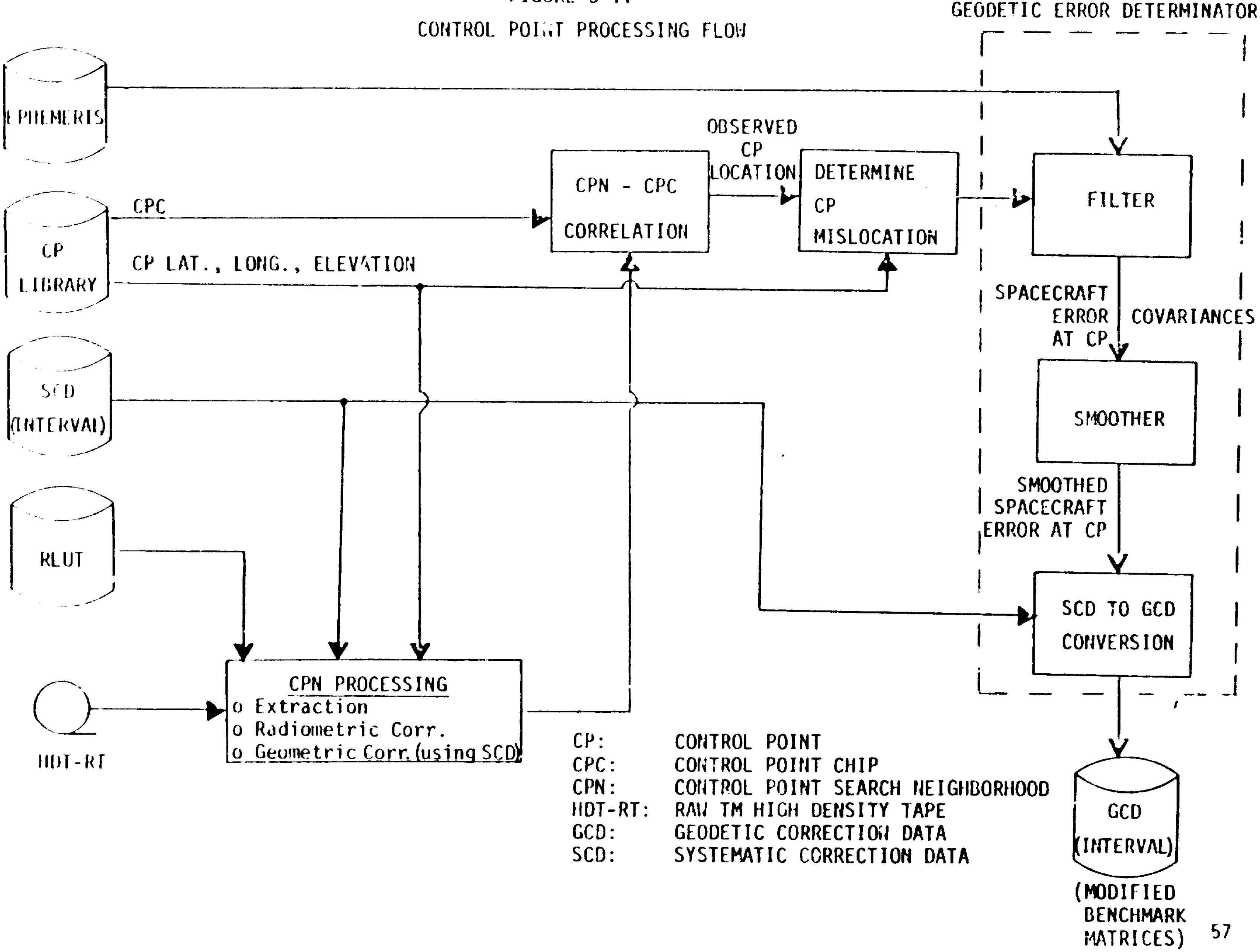
FIGURE 3-11

CONTROL POINT PROCESSING FLOW



CP: CONTROL POINT
CPC: CONTROL POINT CHIP
CPN: CONTROL POINT SEARCH NEIGHBORHOOD
HDT-RT: RAW TM HIGH DENSITY TAPE
GCD: GEODETIC CORRECTION DATA
SCD: SYSTEMATIC CORRECTION DATA

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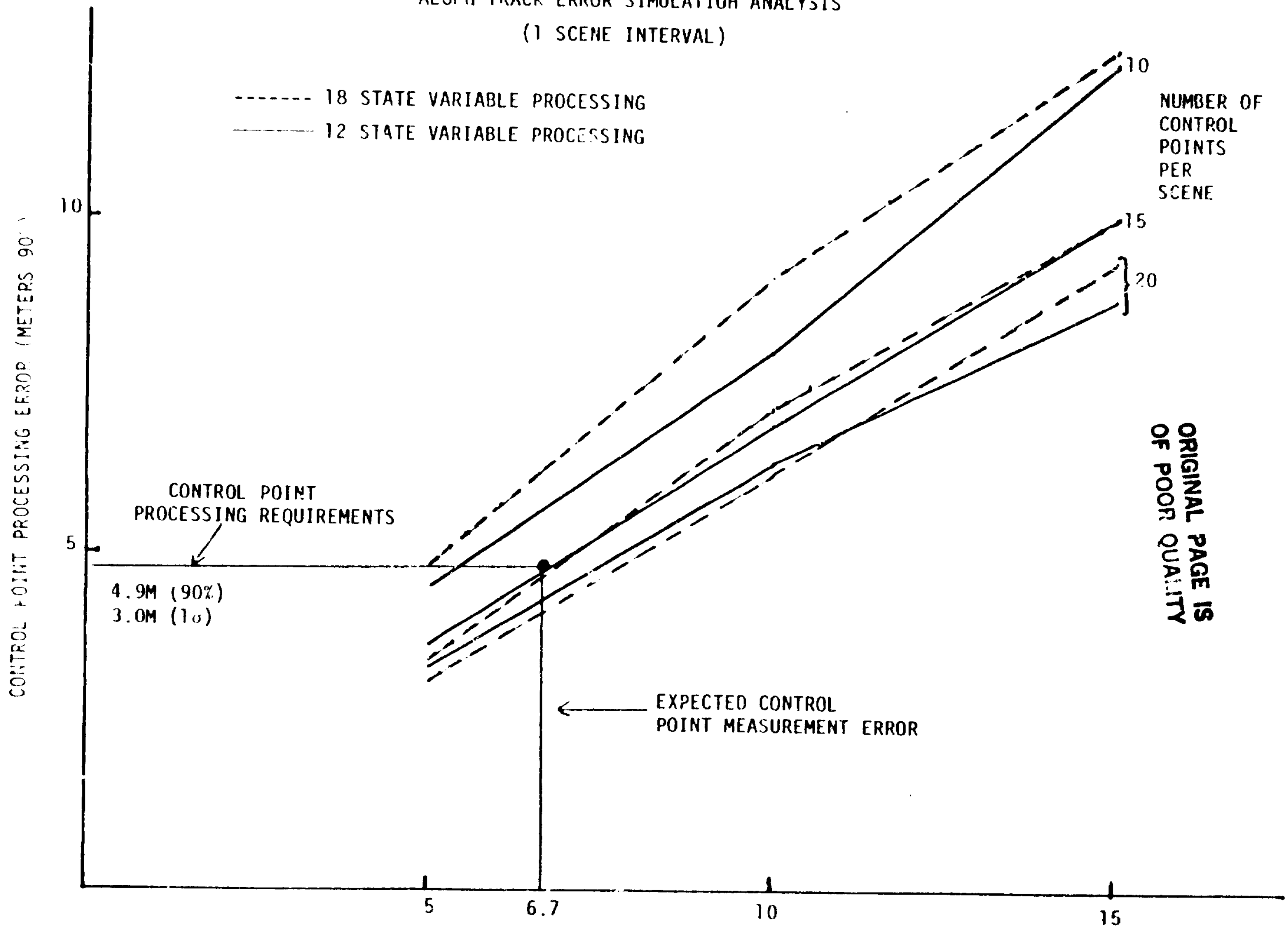
CONTROL POINT PROCESSING
ALONG TRACK ERROR SIMULATIOH ANALYSIS
(1 SCENE INTERVAL)



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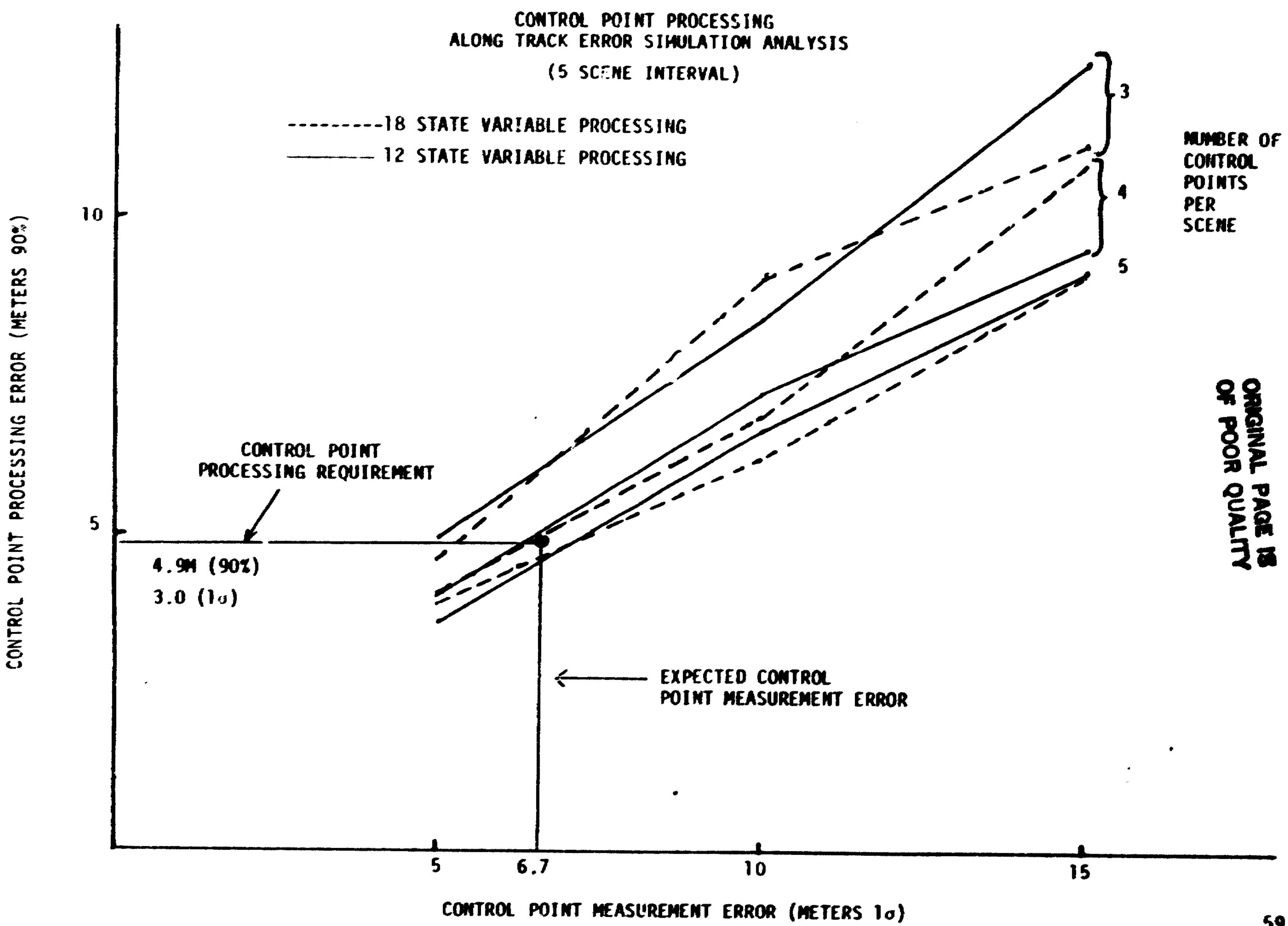

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TM GEOMETRIC CORRECTION PROCESSING

FIGURE 3-12

TM GEOMETRIC CORRECTION PROCESS OVERVIEW

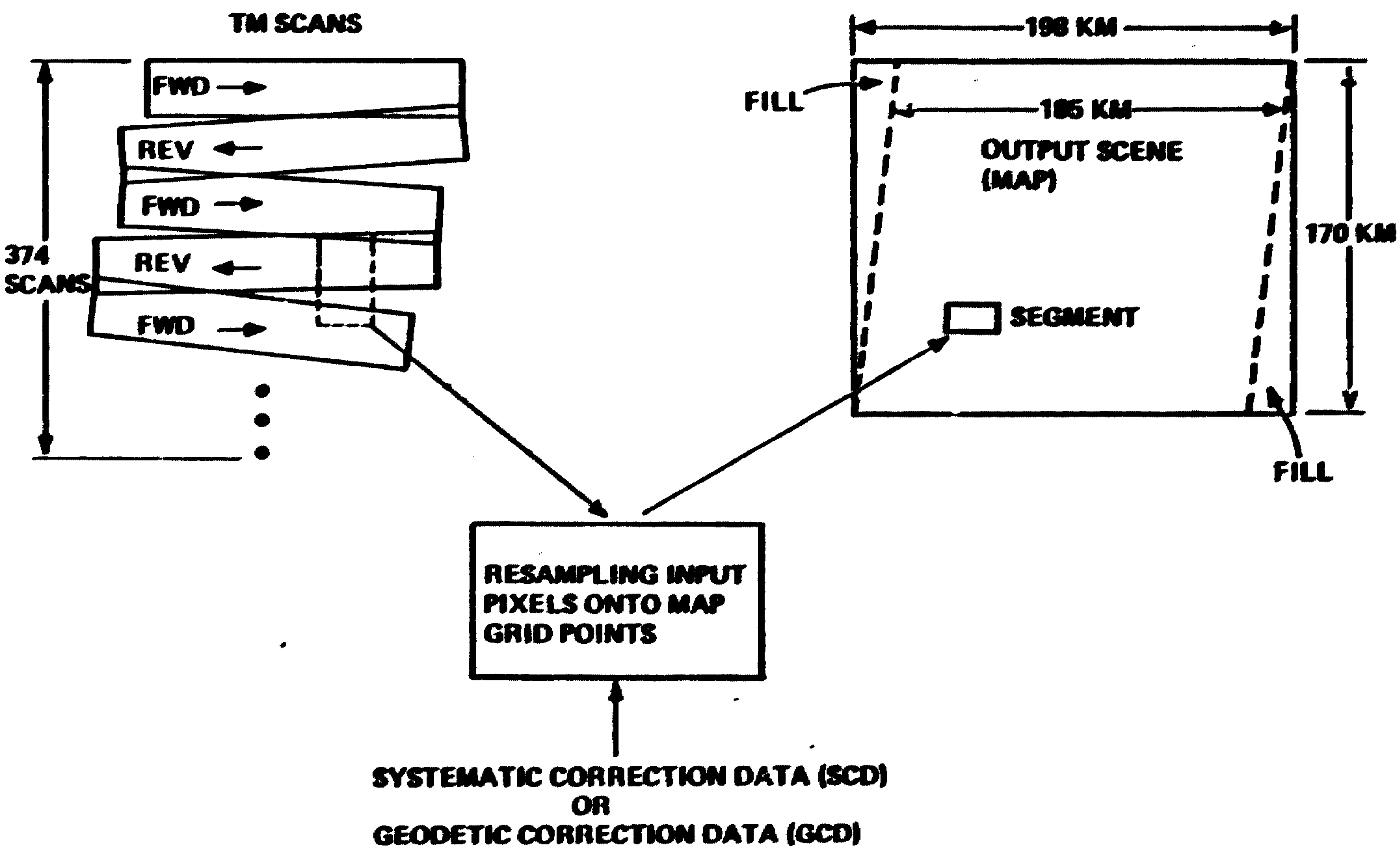

FIGURE 3-13

TWO-DIMENSIONAL CUBIC CONVOLUTION RESAMPLING

- X-RESAMPLING: GENERATE HYBRID PIXELS
- Y-RESAMPLING: GENERATE OUTPUT PIXELS

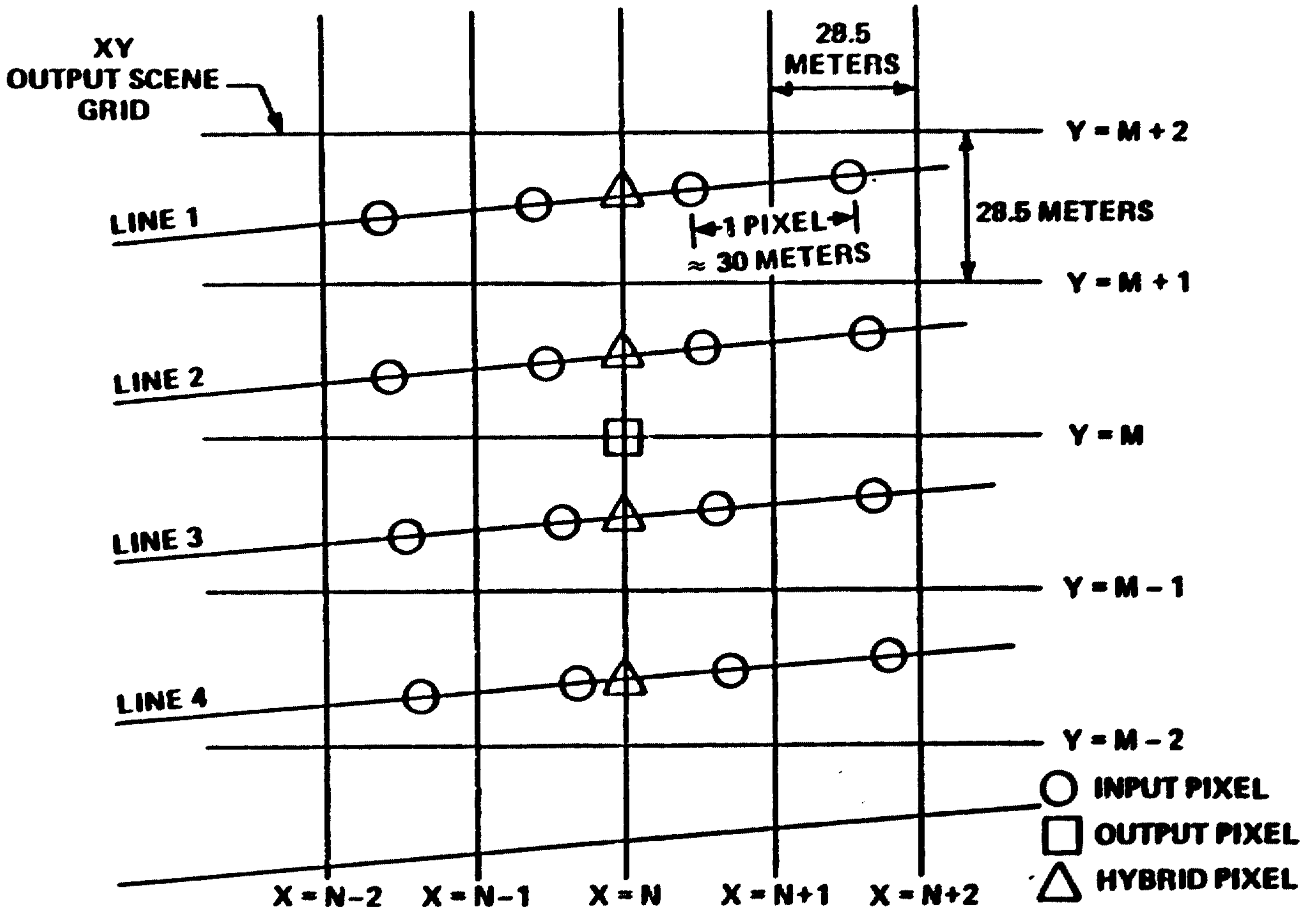

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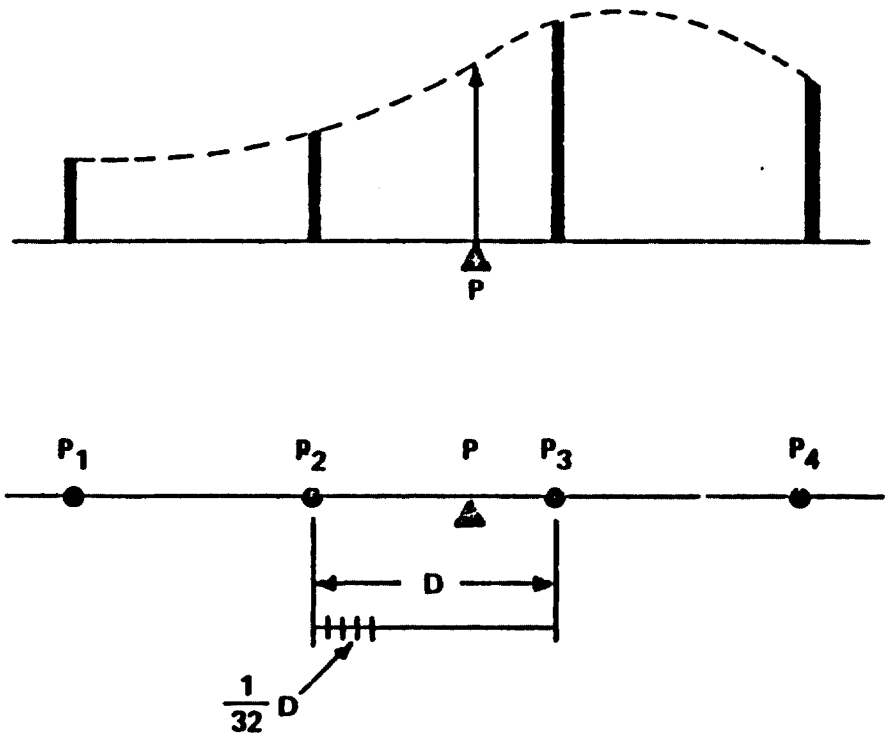
FIGURE 3-14

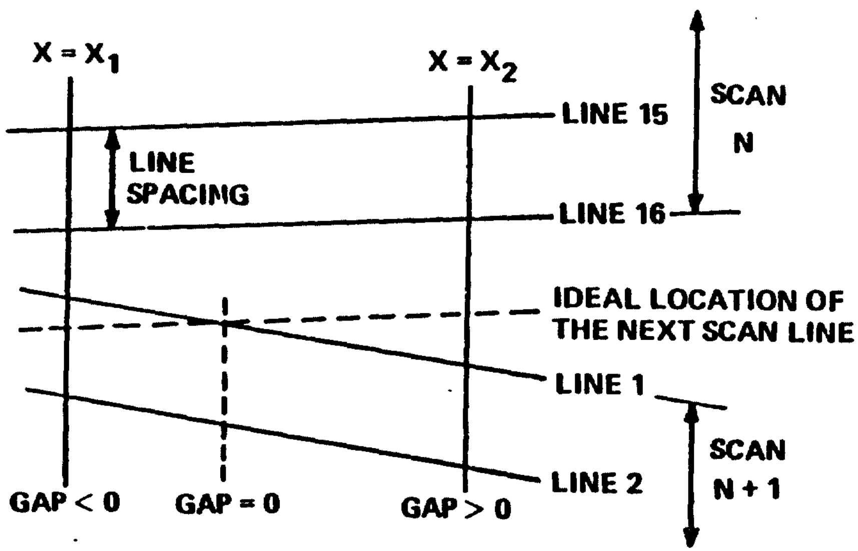
ONE-DIMENSIONAL CUBIC CONVOLUTION RESAMPLING

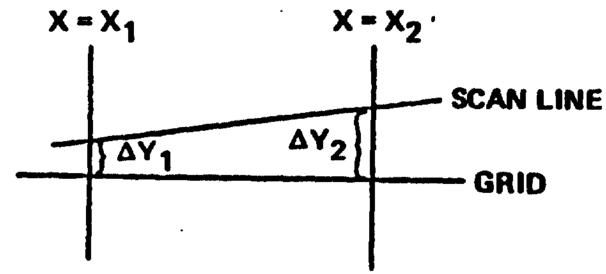


- $P = P_1W_1 + P_2W_2 + P_3W_3 + P_4W_4$
- 32 SETS OF WEIGHTING COEFFICIENTS (W_1, W_2, W_3, W_4) FOR 32 SUB-INTERVALS
- OUTPUT PIXEL LOCATION PRECISION TO (1/64) PIXEL IN RESAMPLING COMPUTATION
- INPUT PIXELS MUST BE EQUALLY SPACED

FIGURE 3-15

SCAN GAP, GAP SKEW AND SCAN LINE SKEW





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- SCAN GAP IS CAUSED PRIMARILY BY ALTITUDE VARIATION, SCAN LINE CORRECTOR SCAN RATE, SPACECRAFT PITCH AND YAW JITTER.
- GAP SIZE = (SPACING BETWEEN LINE 16 AND LINE 1) – LINE SPACING
- GAP SKEW = $\frac{\text{GAP SIZE } (X_2) - \text{GAP SIZE } (X_1)}{X_2 - X_1}$
- SCAN LINE SKEW = $\frac{\Delta Y_2 - \Delta Y_1}{X_2 - X_1}$
- X_1, X_2 = LEFT, RIGHT SIDE OF OUTPUT SEGMENT
- $X_2 = X_1 + 128$

TABLE 3-1

GEOMETRIC CORRECTION OPERATOR (GCO) GAP HANDLING CAPABILITY

	WORST CASE (IN PIXELS)	GCO CAPABILITY (IN PIXELS)
GAP SIZE	–2.8 TO 2.0	-5 TO 3
GAP SKEW OVER 128 OUTPUT PIXELS	–0.42 TO 0.42	-2 TO 2
TM SCAN LINE SKEW OVER 128 OUTPUT PIXELS	–1.0 TO 1.0	-2 TO 2

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THREE – STEP RESAMPLING FOR GAP PROCESSING

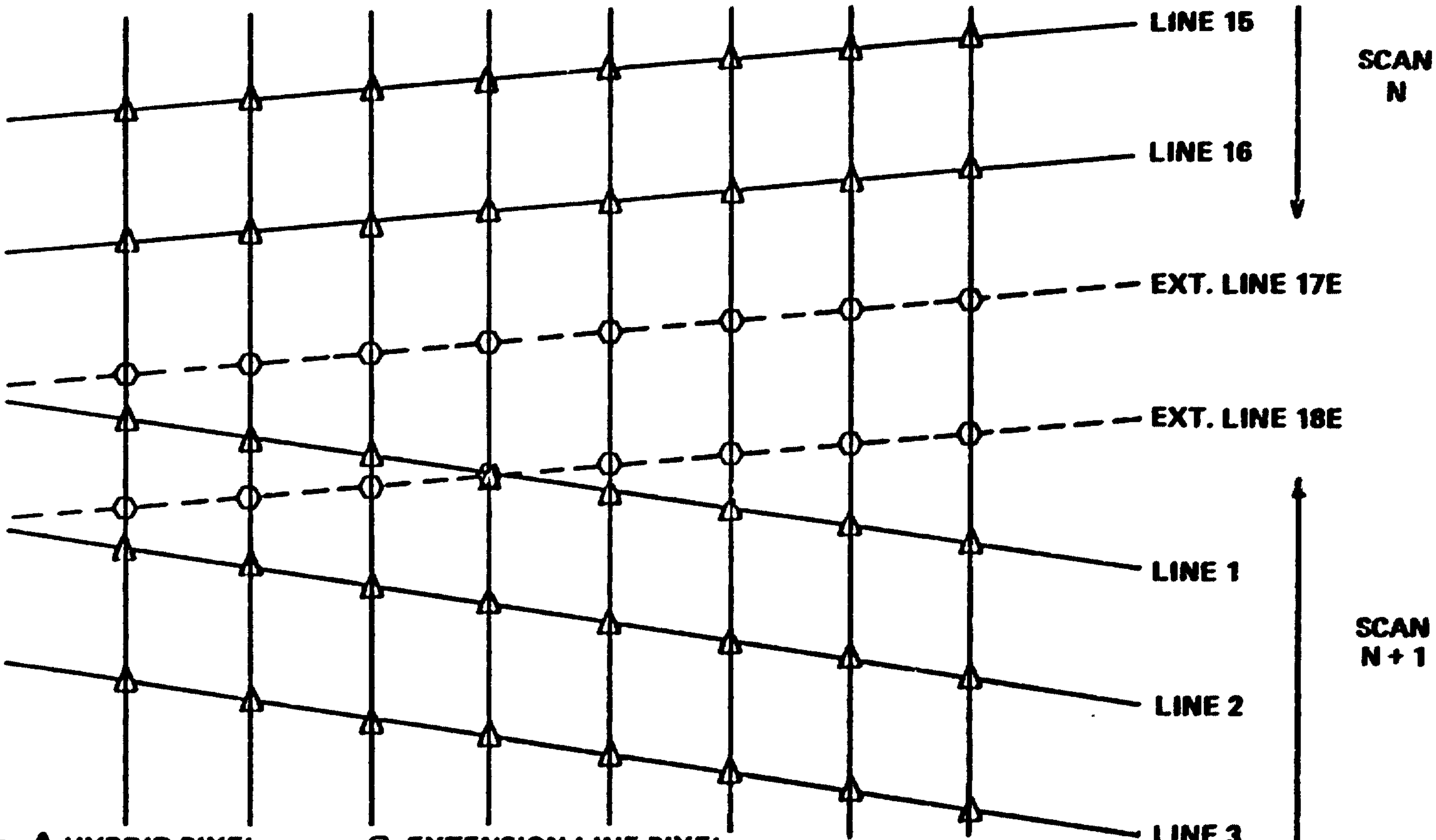
- RESAMPLING ALONG SCAN LINE
- GENERATE PIXELS ON CROSS POINTS OF SCAN LINES AND Y-GRID

- RESAMPLING ALONG Y-GRID
- GENERATE SCAN EXTENSION LINE PIXELS

- RESAMPLING ALONG Y-GRID
- GENERATE PIXELS ON OUTPUT GRID POINTS

FIGURE 3-16

GENERATE SCAN EXTENSION LINE PIXELS



- Δ HYBRID PIXEL　　○ EXTENSION LINE PIXEL
- EXTENSION PIXELS ARE GENERATED WITH TWO HYBRID PIXELS ABOVE AND TWO HYBRID PIXELS BELOW
- PIXEL LOCATION PRECISION TO (1/64) PIXEL IN RESAMPLING COMPUTATION

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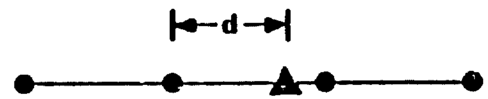
FIGURE 3-17

SPLINE INTERPOLATION FORMULA



● INPUT PIXEL LOCATION
▲ DESIRED PIXEL LOCATION

	CUBIC CONVOLUTION WEIGHT FORMULAS	CUBIC SPLINE WEIGHT FORMULAS
W_1	$-d(1-d)^2$	$\frac{2a_1}{ch_1h_2} f_1f_2f_3 - \frac{1}{ch_1} g_1g_2g_3$
W_2	$(1-d)\ (1+d-d^2)$	$-\frac{1}{ch_1} f_1f_2f_3\left(1+\frac{2a_1}{h_2}+\frac{2a_1}{h_1}\right)+\frac{f_3}{h_2}+\frac{1}{c}g_1g_2g_3\left(\frac{2a_0}{h_2^2}+\frac{1}{h_1}+\frac{1}{h_2}\right)$
W_3	$d(1+d-d^2)$	$\frac{1}{c}f_1f_2f_3\left(\frac{2a_1}{h_2^2}+\frac{1}{h_2}+\frac{1}{h_3}\right)-\frac{1}{ch_2}\left(g_1g_2g_3\right)\left(1+\frac{2a_0}{h_2}+\frac{2a_0}{h_3}\right)+\frac{g_3}{h_2}$
W_4	$-d^2(1-d)$	$-\frac{1}{ch_3} f_1f_2f_3 + \frac{2a_0}{ch_2h_3} g_1g_2g_3$

$f_1 = X_3 - X - h_2$ $\quad g_1 = X - X_2 - h_2$ $\quad h_1 = X_2 - X_1$ $\quad a_0 = h_1 + h_2$

$f_2 = X_3 - X + h_2$ $\quad g_2 = X - X_2 + h_2$ $\quad h_2 = X_3 - X_2$ $\quad a_1 = h_2 + h_3$

$f_3 = X_3 - X$ $\quad g_3 = X - X_2$ $\quad h_3 = X_4 - X_3$ $\quad c = 4a_0a_1 - h_2^2$

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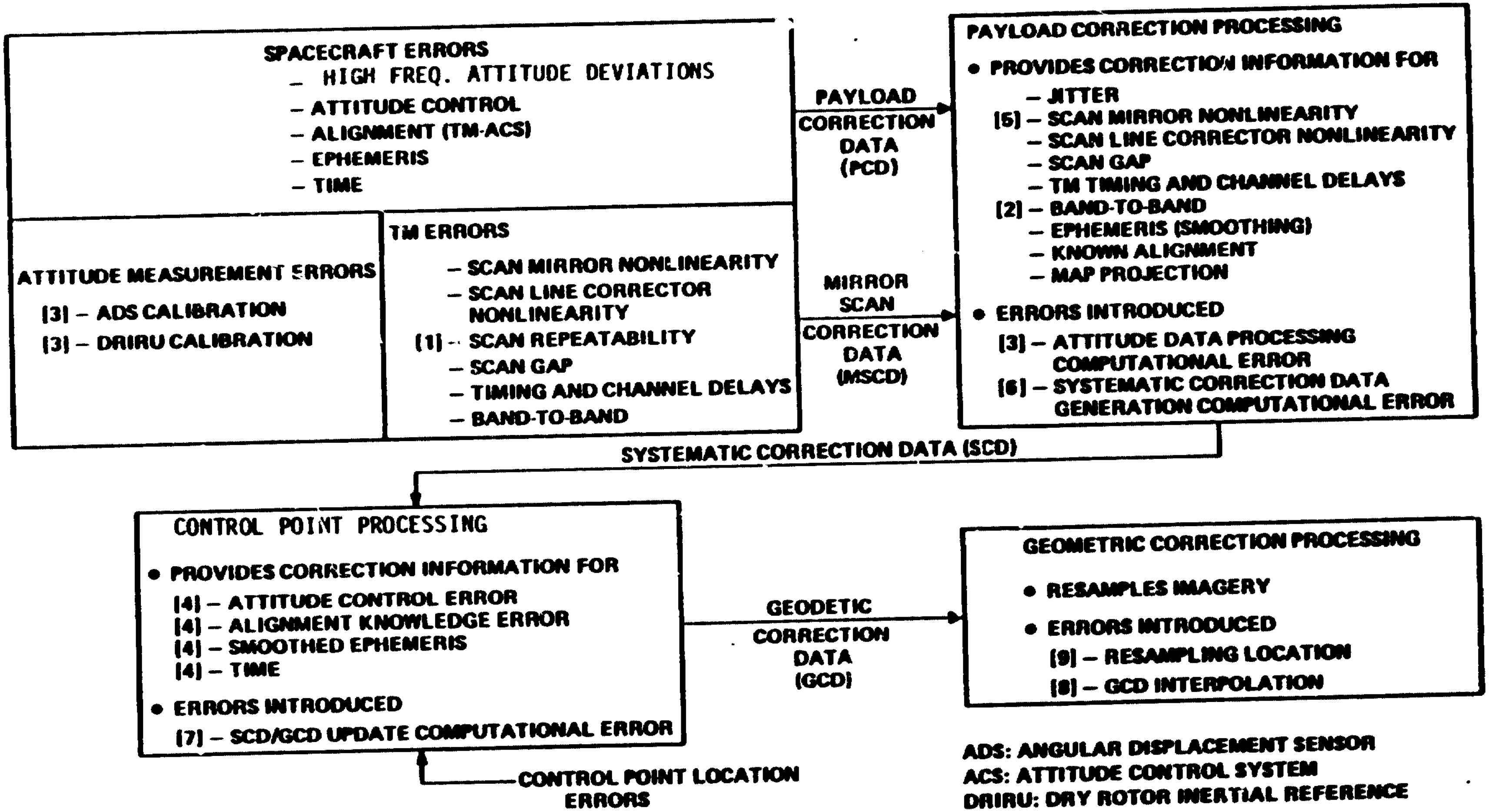
SYSTEM PERFORMANCE

69

TM SYSTEM GEOMETRIC ERRORS



ADS: ANGULAR DISPLACEMENT SENSOR
ACS: ATTITUDE CONTROL SYSTEM
DRIRU: DRY ROTOR INERTIAL REFERENCE UNIT

[•] ERROR BUDGET ITEMS (NEXT CHART)

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70

THEMATIC MAPPER SYSTEM
TEMPORAL REGISTRATION ERROR BUDGET
IN PIXEL (42.5 MICRORAD) 90%

ERROR SOURCE	CROSS TRACK ERROR*	ALONG TRACK ERROR*	ITEM NUMBER (PREVIOUS CHART)
• THEMATIC MAPPER			
– SCAN REPEATABILITY	$.165\sqrt{2}$	$.165\sqrt{2}$	1
– BAND-TO-BAND	$.048\sqrt{2}$	$.039\sqrt{2}$	2
• SPACECRAFT			
– HIGH FREQ. ATTITUDE DEVIATION	$.094\sqrt{2}$	$.094\sqrt{2}$	3
– ATTITUDE, EPHEMERIS, ALIGNMENT, TIME RESIDUAL	.165	.165	4
• GROUND PROCESSING			
– SCAN NONLINEARITY CORRECTION	$.082\sqrt{2}$	0	5
– SYSTEMATIC CORRECTION DATA GENERATION	$.055\sqrt{2}$	$.055\sqrt{2}$	6
– CONTROL POINT PROCESSING	$.055\sqrt{2}$	$.055\sqrt{2}$	7
– GCD INTERPOLATION	$.055\sqrt{2}$	$.055\sqrt{2}$	8
– RESAMPLING LOCATION	$.014\sqrt{2}$	$.014\sqrt{2}$	9
• TOTAL (ROOT-SUM-SQUARE)	.369	.348	
• SPECIFICATION	.3	.3	

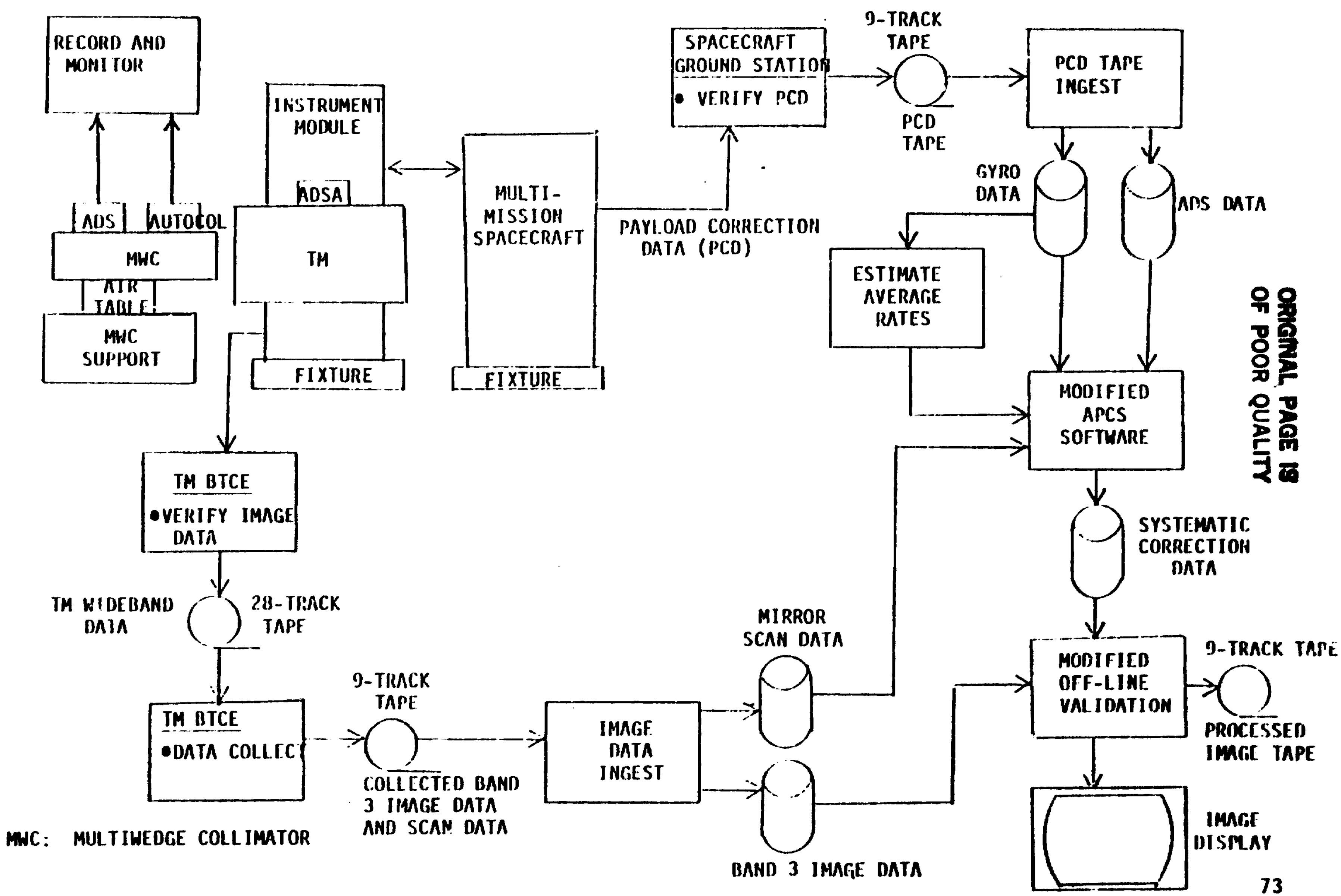
*RESIDUAL ERROR AFTER PROCESSING

TM END-TO-END GEOMETRIC PERFORMANCE TEST

PURPOSE: PRELAUNCH DEMONSTRATION OF FLIGHT HARDWARE AND PROCESSING SOFTWARE

- THEMATIC MAPPER
- ANGULAR DISPLACEMENT SENSOR ASSEMBLY
- PCD FORMATTER
- ATTITUDE DATA PROCESSING
- MIRROR SCAN CORRECTION DATA PROCESSING
- SCD GENERATION
- IMAGE RESAMPLING

END-TO-END TM GEOMETRIC
PERFORMANCE TEST DATA FLOW



MWC: MULTIWEDGE COLLIMATOR

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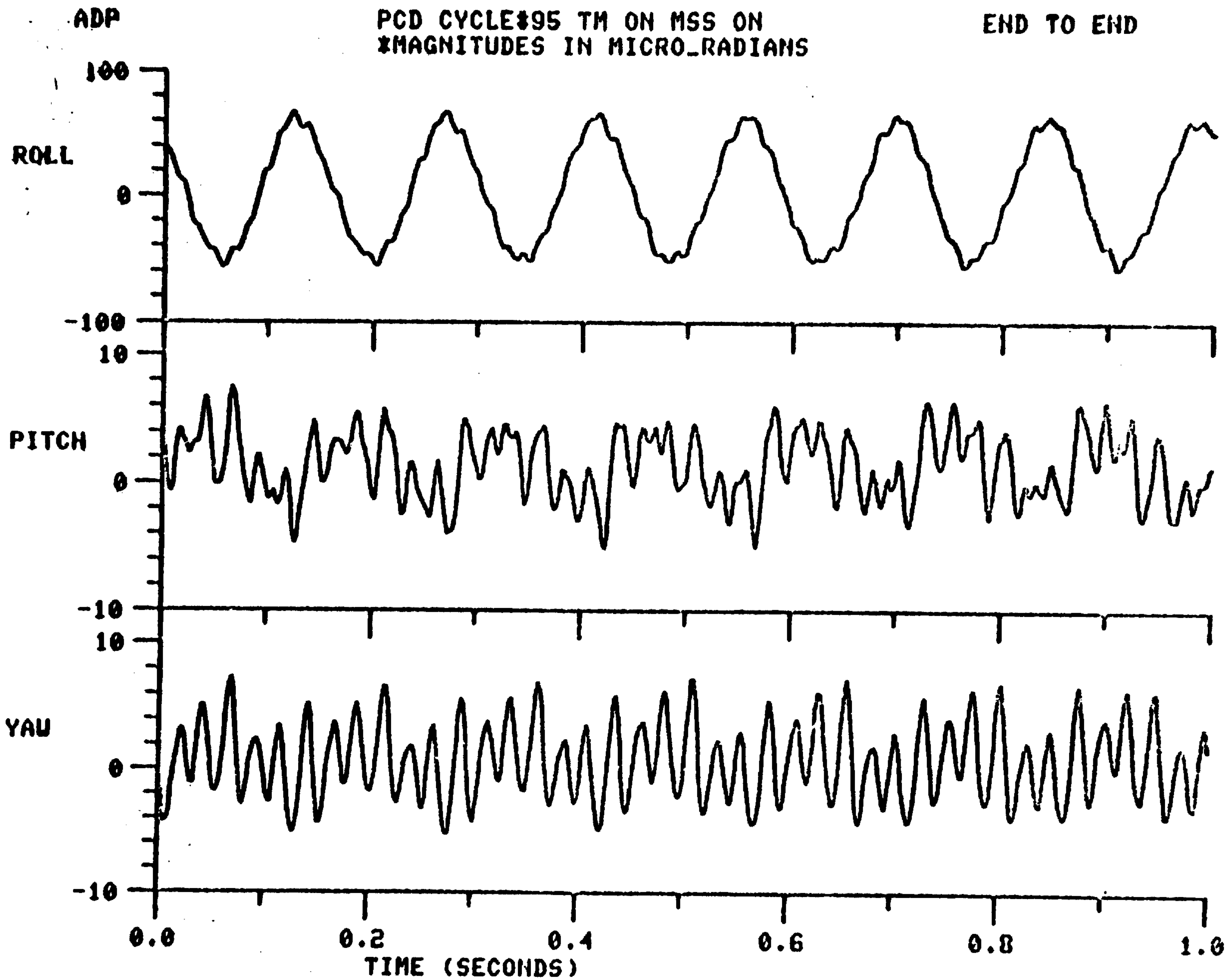
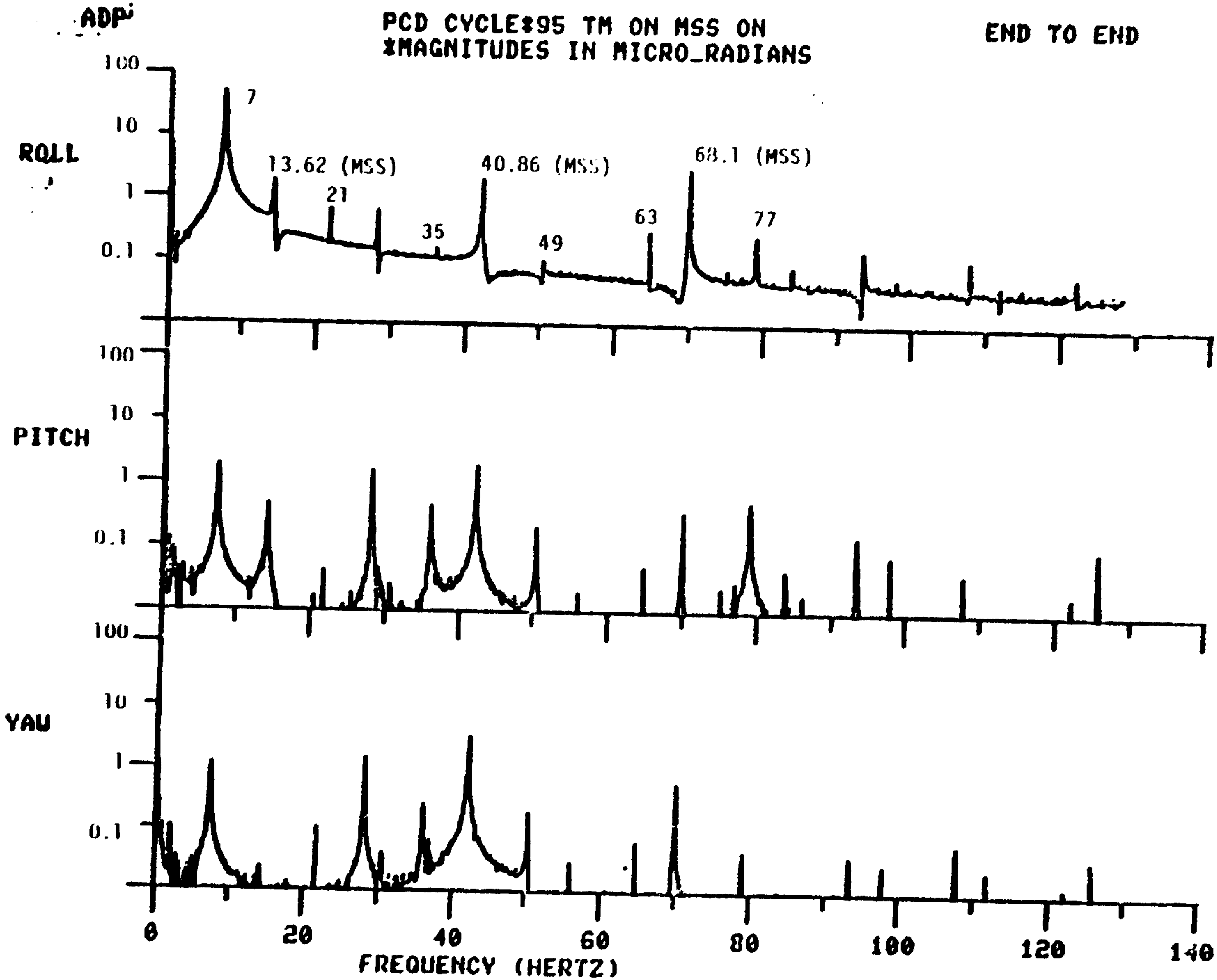


ADP
PCD CYCLE#95 TM ON MSS ON
*MAGNITUDES IN MICRO_RADIANS
END TO END
ROLL
PITCH
YAW
100
0
-100
10
0
-10
10
0
-10
0.0
0.2
0.4
0.6
0.8
1.0
TIME (SECONDS)

74



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TM GEOMETRIC CORRECTION SYSTEM SUMMARY

- FLIGHT SEGMENT
  - ATTITUDE CONTROL
    - 0.01 DEGREE POINTING
    - SOLAR ARRAY CONTROL OPEN-LOOP
    - RANDOMIZED TDRSS ANTENNA CONTROL
  - ATTITUDE MEASUREMENTS
    - DRIRU (0-2 HZ)
    - ADSA (2-125 HZ)
  - STRUCTURAL DYNAMICS CHARACTERIZED
  - THEMATIC MAPPER
    - DEMONSTRATED SCAN REPEATABILITY
- GROUND SEGMENT
  - ATTITUDE DATA PROCESSING

    HIGH FREQUENCY ATTITUDE DEVIATION CORRECTION CAPABILITY
  - MIRROR SCAN DATA PROCESSING

    MID-SCAN PROFILE CORRECTION
  - CONTROL POINT PROCESSING

    MODELED SPACECRAFT ERROR DYNAMICS
  - GEOMETRIC CORRECTION PROCESSING

    GAP RESAMPLING CAPABILITY
- PRELAUNCH PERFORMANCE SIMULATIONS AND TESTING
- POST LAUNCH CALIBRATION AND VALIDATION

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Early Access
TM Processing

Dave Fischel

LAS Component Objectives

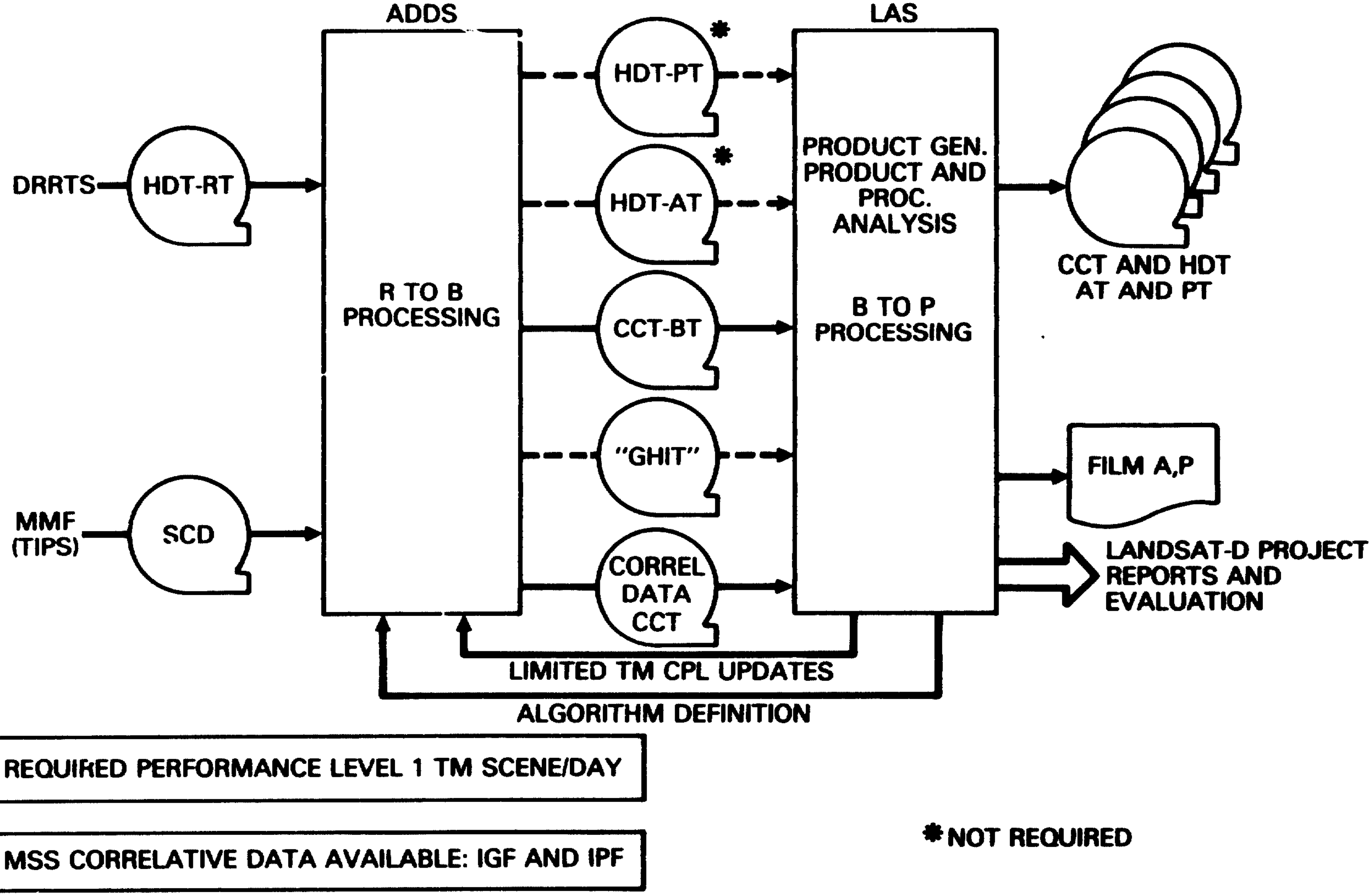
PRODUCT GENERATION

- ACQUIRE FROM ADDS ONE TM SCENE/DAY FOR
  - USE BY LAS PAPA
  - PRODUCTION OF FILM, HDT, CCT AT A AND P LEVELS

PRODUCTS AND PROCEDURES ANALYSIS (PAPA)

- DEVELOP AND EVALUATE A PRIORI GROUND PROCESSING PROCEDURE FOR RADIOMETRIC AND GEOMETRIC CORRECTION INCLUDING JITTER
- INSTITUTE AND EVALUATE INDICATED MODIFICATIONS TO A PRIORI PROCEDURE
- ISSUE REPORTS AND/OR RECOMMENDATIONS TO LANDSAT-D PROJECT IN RE PROCEDURE AND PRODUCT CHARACTERISTICS

TM Early Access Program Functional Data Flow



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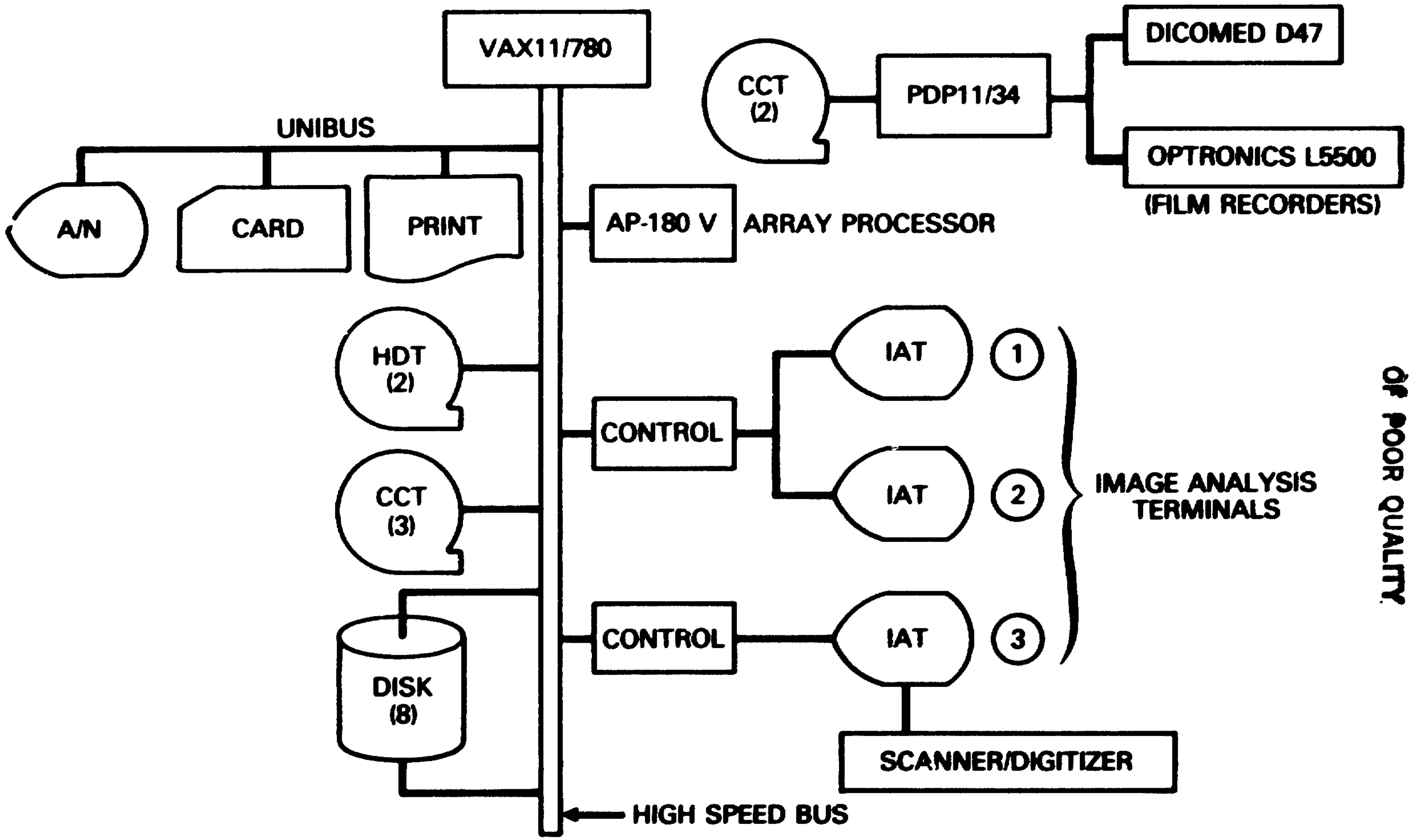
MAJOR FUNCTIONAL DATA FLOW
—TM PROCESSING—

Overall Configuration



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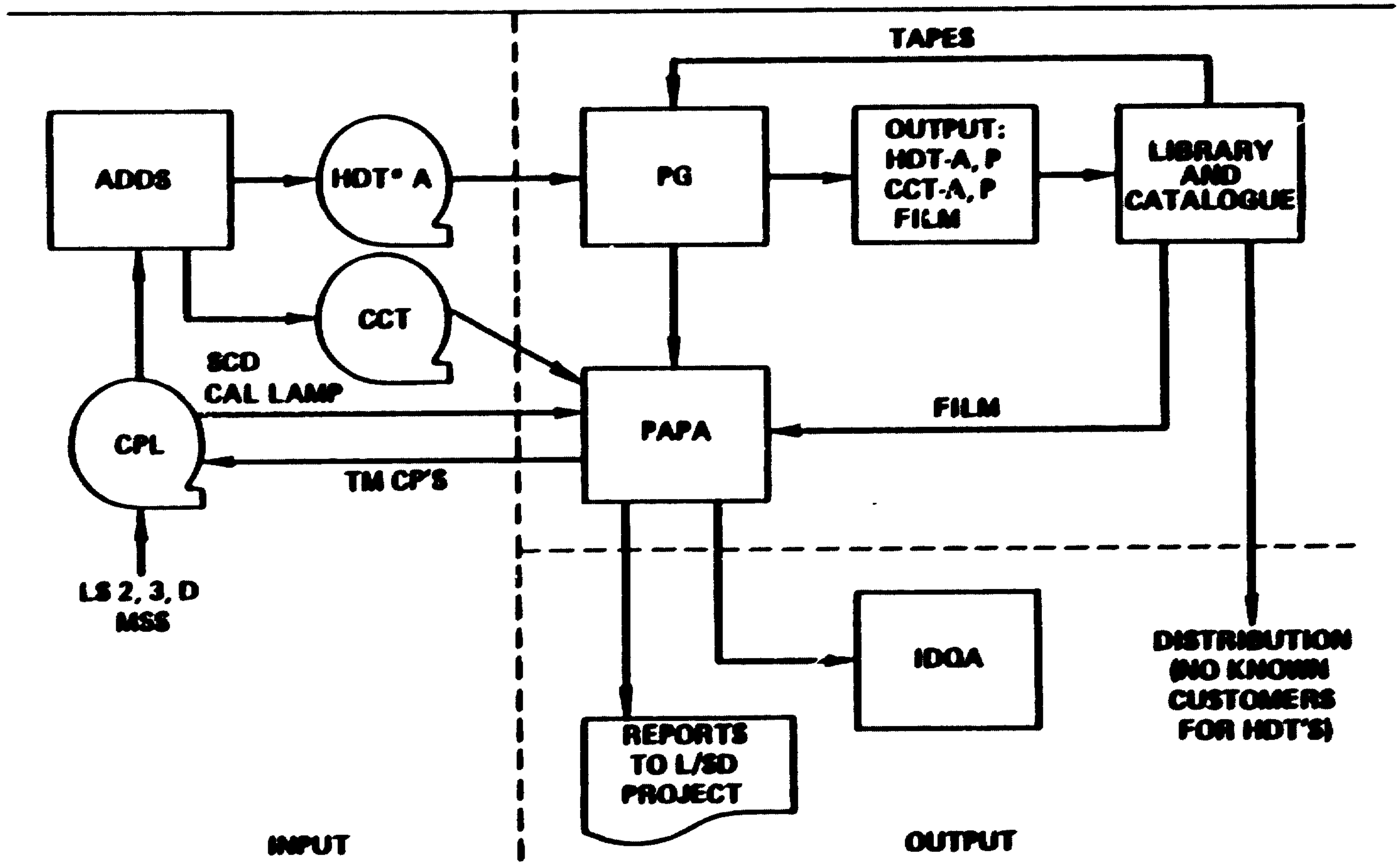
Data Flow



*OR EQUIVALENT BSQ 6250 BPI WITH VARIOUS RLUT OPTIONS

LEGEND

IDQA = IMAGE DATA QUALITY ANALYSIS
PG = PRODUCT GENERATION
PAPA = PRODUCT AND PROCEDURES ANALYSIS
CPL = CONTROL POINT LIBRARY

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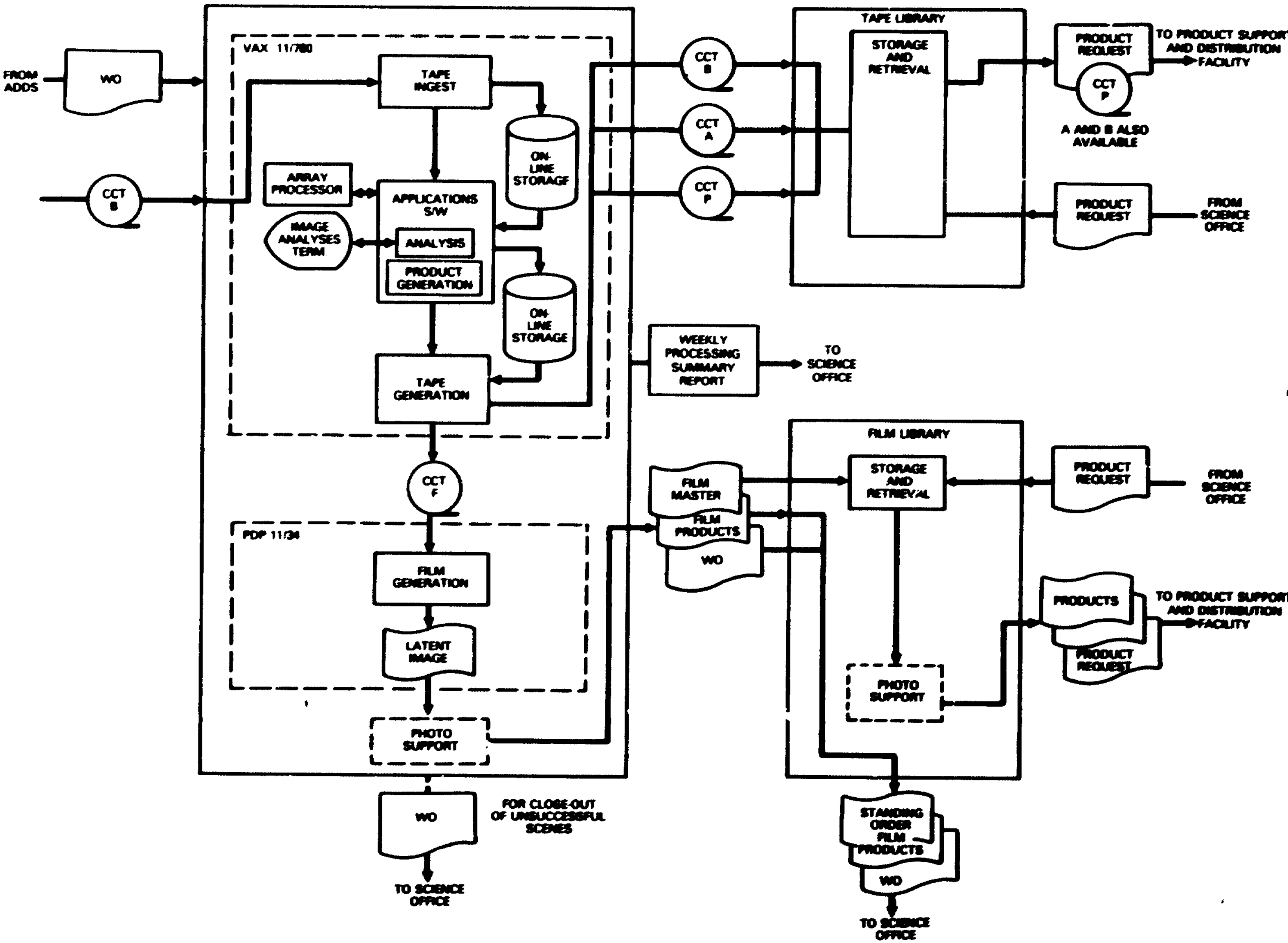
LAS Internal Data Flow



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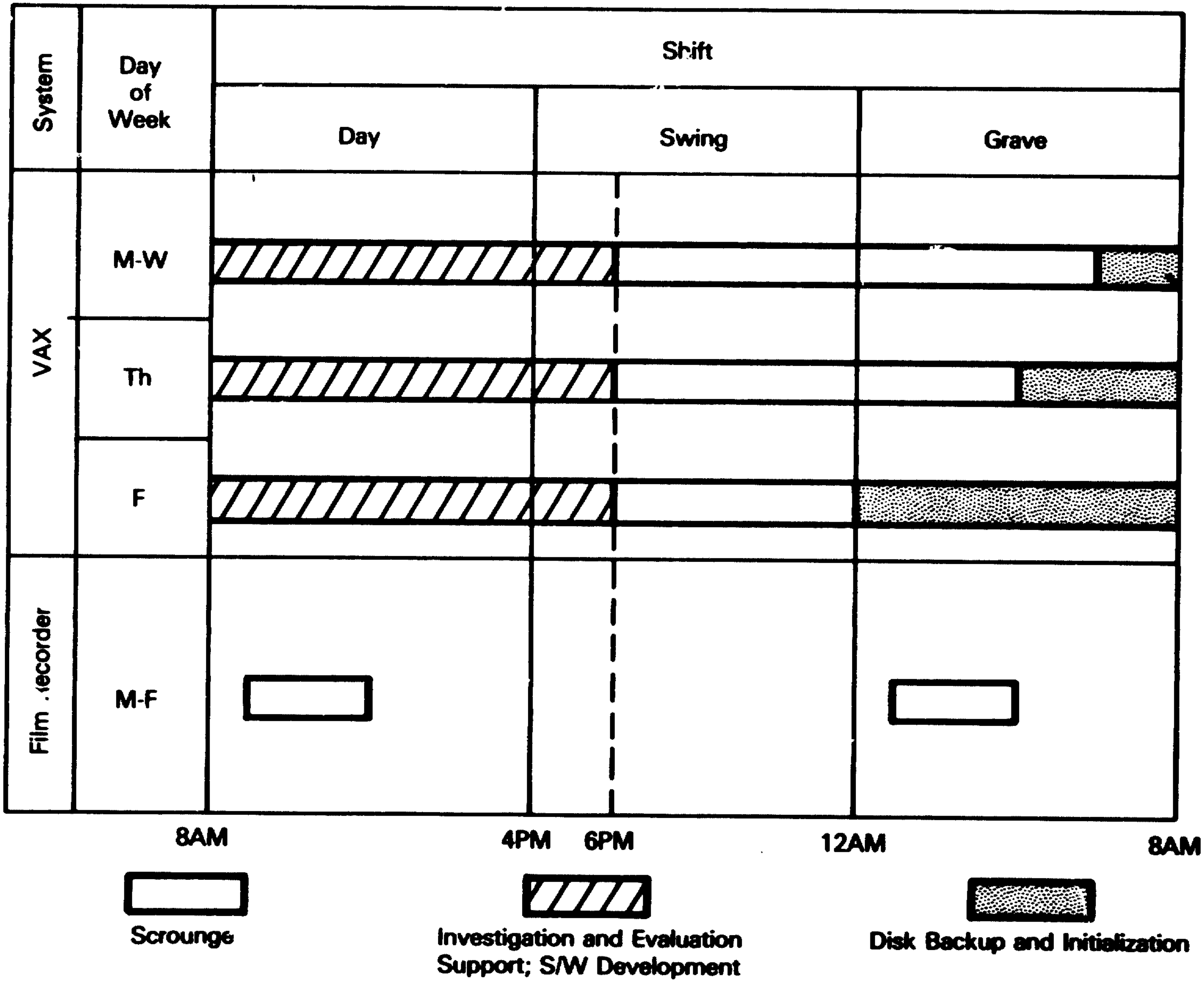
LAS Functions

- Receive a Minimum of 10 and up to 21 TM Scenes Per Week in CCT-B Format
- Receive Corresponding Work Orders and Scene Priorities
- Apply Radiometric and Geometric Corrections to TM Data as Required to Produce CCT-A and P Products
- Produce TM P-Film Master and Associated Products for 7 Scenes Per Week
- Forward Standing Order Film Products and Updated Work Orders to Science Office
- Store Tape and Film Master in Respective Libraries
- Supply Film and Tape Masters to Products Support and Distribution Facility (According to Product Requests) for Preparation of Output Products
- Provide Science Office with Weekly Processing Summary Report

LAS Scrounge Operations Schedule



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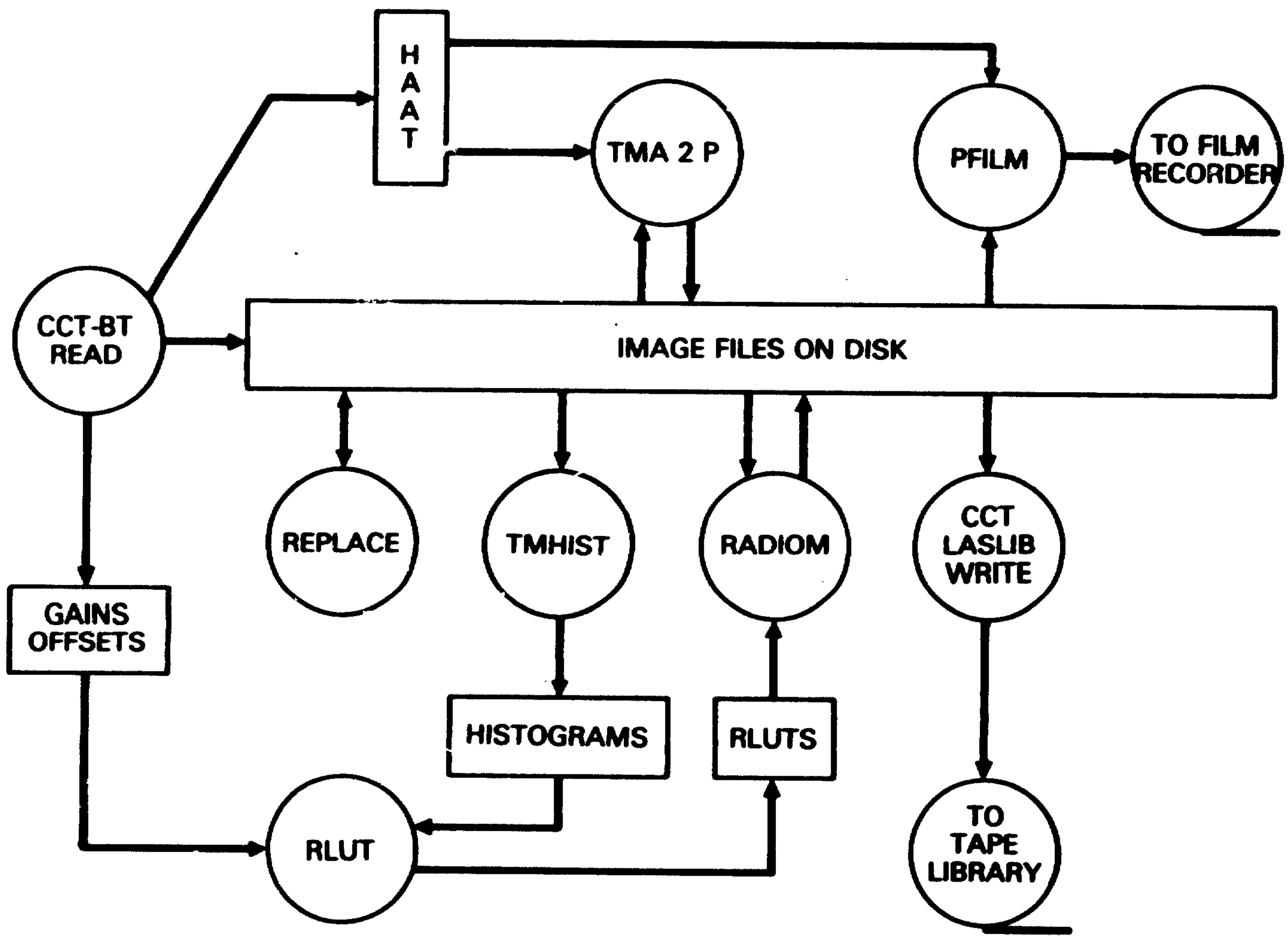
"Scrounge" Data Flow



HAAT: HEADER, ANCILLARY, ANNOTATION AND TRAILER RECORDS

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LAS Tape P Level Data Content

HAAT FILE

- Usual Scene Identifiers and Processing Flags
- Ephemeris Data for **INTERVAL** Containing Scene
- TM Housekeeping Data for **INTERVAL** Containing Scene
- QA Data for Attitude Sensors
- SCD (Systematic Correction Data) SOM/UTM
- Annotation Records and Tick Mark Data

IMAGE LABEL FILES (1 per band)

- Data Definition Record
- Processing History Records (Textual)

IMAGE FILES (1 per band)

- BSQ Image Data P Level Data

Vol. 1	Vol. 2	Vol. 3
HAAT	Band 3	Band 5
Band 1	Band 4	Band 6
Band 2		Band 7

LAS P Film Format

Looks Like the Familiar Format with Tick Marks Around the Outside, Annotation Lines and a Grey Scale Wedge.

Differs from (Probable) TIPS Format by

- No Registration Marks
- No Resolution Target
- No Image Overlap Marks
- Tick Marks are Straight Lines—Not Crosses
- Extra Annotation Line for Agency and Generation Date

Definition of Application Software Divisions

MISSION READINESS:	1) DIRECT SUPPORT FOR PRODUCTION OF P LEVEL PRODUCTS 2) ANALYSIS OF CALIBRATION LAMP AND SYSTEMATIC CORRECTION DATA (SCD)
AT LAUNCH:	BASIC MAIN LINE IMAGE PROCESSING PROGRAMS; ESPECIALLY SUPPORT OF PRODUCTS AND PROCEDURES ANALYSIS (PAPA) TASKS
POST LAUNCH:	ALL REMAINING MAIN LINE IMAGE PROCESSING PROGRAMS PLUS RESEARCH AND DEVELOPMENT ITEMS TO BE DEFINED BY INVESTIGATORS (CROSS HATCHED IN DATA FLOW DIAGRAMS THAT FOLLOW)

LAS In-Line and Post-Launch Applications Software

	Preprocessing	Radiometry	Geometric	Image Manipulation	Display Manipulation	Interpretation and Analysis
INLINE	REPLACE	$\boxed{\text{CALAMP}}$	TMA2P		SETIAT	
	$\boxed{\text{TMHIST}}$	$\boxed{\text{RLUT}}$	$\underbrace{\text{JITTER}}$		LUTLOD	
	RLUT	$\underbrace{\text{RADIOM}}$	$\underbrace{\text{SCDFT}}$			
	COPY					
POST LAUNCH	LINEREPR	HISTEQ	EDGECORR*	STRETCH	(UTILITIES)	STATS
	SEGMREPR		GEOM*	ZOOM	SITES	DROPSITE
	DESPIKE		MSSA2P*	CONCAT	COLGEN	XFERSITE
	FFT1		GCDG*	EDGE	LUTEDT	EDITSITE
	FFT1FL			CONVOLVE	LUTSAV	LISTSTAT
	FFT2			UNARY (5)	GRAPHICS	RENCLS
	FFT2FL			BINARY (7)	CHAROUT	COMBCLS
	WTGEN			SCALE		DROPCLS
	LIST			MEDFIL		BAYES
	SHADE			FT2PIX		
	FILM			FT2PIX		
	CLASSMAP					

$\boxed{\text{NAME}}$ Will Disappear After "SCROUNGE"
$\underbrace{\text{NAME}}$ May Disappear, Be Modified and/or Have Low Usage
NAME* Due About 3 Mos. After Launch (Many Others Not Listed)

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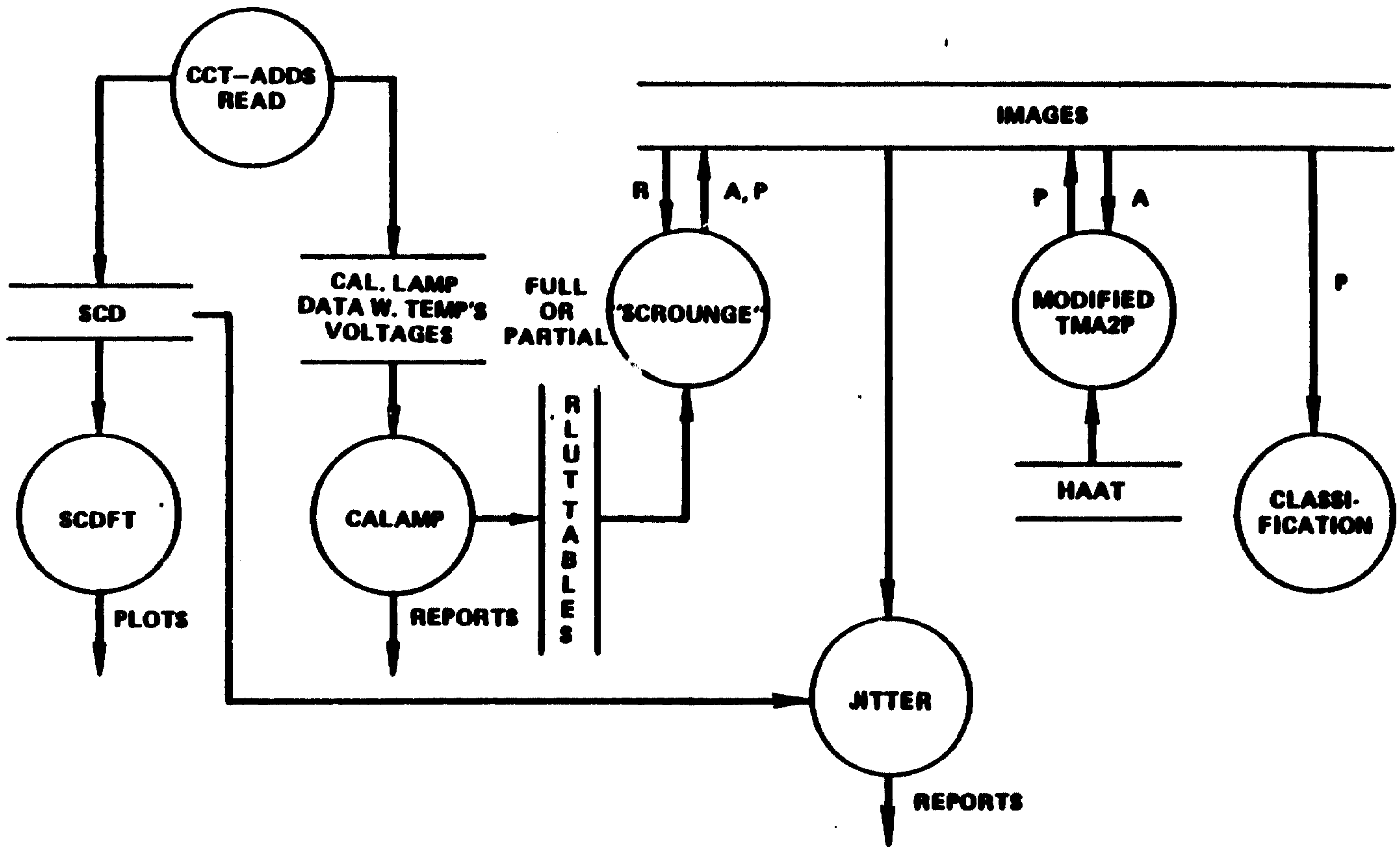
Representative PAPA Data Flow(s)



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Wrap-Up Panel Discussion

Science Team

AAT	Archival Ancillary (Data) Tape
ACCA	Automatic Cloud Cover Assessment
ACE	Attitude Control Electronics
ACS	Attitude Control System
ACT	Application Concept Test
A/D	Analog to Digital
ADCP	See ANDP
ADDS	Applications Developmental Data System
ADFS	Automated Digital Facsimile System
ADL	Applications Development Laboratory
ADP	Automatic Data Processing
ADPE	Automatic Data Processing Equipment
A&DS	Aerospace and Data Systems
ADS	Angular Displacement Sensor or Angle Detector Sensor
ADT	Ancillary Data Tape
AEM	Applications Exploratory Mission
AFGWC	Air Force Global Weather Central
AFOS	Automation of Field Operations and Services
AFPRO	Air Force Plant Representative Office
AG	Archive Generation
AGC	Automatic Gain Control
AGE	Aerospace Ground Equipment
AGS&PO	Aerospace Group Strategic Planning and Programs Office
Ahr	Ampere - hour
ALU	Algorithm Logic Unit
AMS	Attitude Measurement System
AN	Applications Notice
ANCP	See ANDP
ANDP	Ancillary Data Calculation Process
ANSI	American National Standards Institute
ANT	Ascending Node Table
AO	Announcement of Opportunity
AOIPS	Atmospheric and Oceanographic Image Processing System
AOP	Advanced Onboard Processor
AOS	Acquisition of Signal
AP	Applications Processor
AP	Array Processor
APFO	Aerial Photography Field Office
APL	Applied Physics Laboratory (John Hopkins Univ.)
APS	Antenna Positioning System
ASCII	American Standard Code for Information Interchange
ASPR	Aerospace Strategic Programs Representation
ASPR	Armed Services Procurement Regulations
ASR	Automatic Send/Receive
AST	Asynchronous System Trap
ASVT	Applications System Verification and Transfer Project

AT	Acceptance Test
ATL	Applications Technology Laboratory
ATM	Antenna Test Model
ATM	Apollo Telescope Mount
ATP	Acceptance Test Plan
ATS	Applications Technology Satellite
AWG	American Wire Gauge
BARDJA	Boom Antenna Retention Deployment and Jettison Assembly
BAT	Bench Acceptance Test
BB	Build Baseline
BCU	Bus Coupling Unit
BDF	Block Data Format
BER	Bit Error Rate
BESS	Biological Experiment Scientific Satellite
BFR	Browse Film Recorder
BIC	Band Interleaved by Cylinder
BIL	Band Interleaved by Line
BIP	Band Interleaved by Pixel
BIW	Band Interleaved by Word
BOL	Beginning of Life
BOS	Beginning of Scan
BOT	Beginning of Tape
B&P	Bid and Proposal
BPA	Bus Protection Assembly
bpi	Bits per Inch
BPI	Bytes per Inch
bps	Bits per Second
BPS	Bytes per Second
BSE	Broadcast Satellite Experimental
BSQ	Band Sequential
BSR	Back Surface Radiator
BTC	Bench Test Cooler
BTCE	Bench Test and Calibration Equipment
BTE	Bench Test Equipment
B/U	Backup
B&W	Black and White
CAL	Configured Articles List
CAL	Calibration
CARETS	Central Atlantic Regional Ecological Test Site
CASH	Catalog of Available and Standard Hardware
CAT	Catalog
CCA	Cloud Cover Assessment
CCB	Configuration Control Board
CCC	Camera Controller Combiner

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CCD	Charge Coupled Device
CCL	Closed Circuit Loop
CCM	Color Composite Master
CCN	Contract Change Notice
CCP	Cloud Cover Assessment Process
CCT	Computer Compatible Tape
CCT-A	CCT Containing Partially-Corrected Data
CCT-AM	CCT Containing Partially-Corrected MSS Sensor Data
CCT-AT	CCT Containing Partially-Corrected TM Senor Data
CCT-B	CCT Produced by ADDS
CCT-P	CCT Containing Fully-Corrected Data
CCT-PM	CCT Containing Fully-Corrected MSS Sensor Data
CCT-PT	CCT Containing Fully-Corrected TM Sensor Data
CDD	Cartridge Removable Diablo Disk Drive
C&DH	Command and Data Handling
CDHS	Command and Data Handling System
CDHSS	Command and Data Handling System Simulator
CDHSS I/U	CDHSS Interface Unit
CDR	Conceptual Design Review
CDR	Critical Design Review
CDRB	Conceptual Design Review Board
CDRL	Contract Data Requirements List
CEM	Controlled Environment Module
CFOV	Clear Field-of-View
CG	Center of Gravity
CI	Configuration Item
CLD	Cloud
CLL	Corrected Line Length
CM	Center of Mass
C.M.	Configuration Management
CMD	Command
CMI	Configuration Management Instruction
CMM	Command Memory Management
CMO	Configuration Management Office
COBOL	Common Business Oriented Language
COMP	Computer
C.P.	Center of Pressure
CP	Communication Processor
CP	Control Point
CPC	Control Point Chip
CPCI	Computer Program Configuration Item
CPD	Control Point Directory
CPDS	Computer Program Design Specification
CPD-U	Control Point Directory (Candidate for Permanent File)
CPG	Correction and Product Generation Software
CPL	Control Point Library
CPL-U	Control Point Library (Candidate for Permanent File)
cpm	Cards per Minute
CPM	Computer Personality Module
CPN	Control Point Neighborhood
CPN-G	Control Point Neighborhood for Geodetic Corrections
CPN-L	Control Point Neighborhood for Library Maintenance
CPN-M	Control Point Neighborhood for MSS
CPN-T	Control Point Neighborhood for TM
CPPT	CZCS Preprocessor Performance Tape
CPR	Cloud Physics Radiometer
CPU	Central Processing Unit
CR	Card Reader
CRC	Cyclic Redundancy Check
CRIS	Cosmic Ray Ionization Spectrometer
CRT	Cathode Ray Tube
CSA	Cropping, Subsampling and Averaging
CSC	Computer Sciences Corporation
CSE	Contractor Supplied Equipment
CSF	Control and Simulation Facility
CSS	Coarse Sun Sensor
CU	Central Unit
CY	Calendar Year
CZCS	Coastal Zone Color Scanner
D/A	Digital-to-Analog
DAS	Data Base Administration Subsystem
DAS^3	De-Centralized Automated Service Support System
DB	Data Base
DBIP	Data Base Interface Process
dBi	Antenna gain in decibels referenced to an Isotropic Antenna
dBm	Power in decibels referenced to one millimeter
DBMS	Data Base Management System
DBMS-10	DEC-10 System Software for Data Base Management
DC	Direct Current
DCP	Data Collection Platform
DCS	Data Collection System
DCST	Data Collection System Tape
DDG	Digital Display Generator
DDI	Digital Data Interconnect
DDL	Data Description Language
DDP	Digital Data Processor
DDP-C	Controlled Environment Module DDP
DDP-W	Wire-Wrapped DDP
DDR	Detailed Design Review
DDRB	Detailed Design Review Baseline
DEC	Digital Equipment Corporation
DEC-10	DEC-10 Computer
DEC-20	DEC-20 Computer
DECnet	Digital Equipment Corporation Communications Network
DECOM	Decommutator
DECOM	Decommutation Hardware Device
DEMUX	Demultiplexer
DFP	Data Formatter Processor
DFS/ADFS	Digital Facsimile System/Automated Digital Facsimile System
DIAL	Digital Image Analysis Laboratory
DICOMED	Film Recorder Vendor
DID	Digital Image Data
DIP	Dual Inline Package
DIPS	Digital Image Processing System
DKIO	Large Image Access Routines
D/L	Downlink
DMA	Direct Memory Access
DMF	Data Management Facility
DML	Data Management Language
DML	Data Manipulation Language
DMS	Data Management System

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DMSP	Defense Meteorological Satellite Program
DOC	Data Operations Control
DOD	Department of Defense
DOD	Depth of Discharge
DOI	Department of the Interior
DOI/EDC	Department of the Interior/EROS Data Center
DOMSAT	Domestic Communications Satellite
DPM	Drafting Practices Manual
DPR	Design Problem Report
DPS	Data Processing System
DPS	DRRTS Process Software
DPSE	DRRTS Process Software Executive
DPU	Digital Processing Unit
DR11C	Programmed Input Output Interface Device for DEC Unibus
DR70	Direct Memory Access Interface Device for DEC Massbus
DR780	Direct Memory Access Interface Device for DEC VAX-11/780
DRIRU	Dry Rotor Inertial Reference Unit
DRRTS	Data Receive, Record and Transmit System
DS	Dimension (Telephone) System
DSC	Data Collection System
DSCS	Defense Satellite Communications System
DSCS	Desk Side Computer System
DSI	Digital Subsystem Interface Unit
DSL	Data Service Laboratory
DSM	Downlink Synchronization Module
DSSCI	Data Stripper-Serial Controller Interface
DSU	Digital Switching Unit
DTD	Digital Terrain Data
DTM	Digital Terrain Map
DTG	Digital Tape Generation
DTR	Daily Test Report
DTS	Digital Transmission System
DV	Digital Voltmeter
DX20	DEC Peripheral Interface Device
DXFP	Data Extraction and Formatting Process
EAGE	Electrical Aerospace Ground Equipment
EBCDIC	Extended Binary Coded Decimal Interchange Code
EBR	Electron Beam Recorder
EBRIC	Electronic Beam Recorder Image Correction
ECC	Error Correction Capability (HDDR)
ECEF	Earth-Centered-Earth-Fixed
ECI	Earth-Centered-Inertial
ECL	Emitter Coupled Logic
EDC	EROS Data Center
EDIPS	Electronic Digital Processing System
EDIPS	EDC Digital Image Processing System
EDP	Electronic Data (Digital) Processing
EDPS	Electronic Data Processing System
EED	Electro-Explosive Device
EF	Earth Fixed Coordinate System
EGRET	Explorer Gamma Ray Experiment Telescope
EGSE	Electrical Government Supplied Equipment
EI	Engineering Instruction
EIA	Electronic Industries Association
ELE	Elevation at Entry
ELS	End-of-Line Sync
ELX	Elevation at Exit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ENA/DISA	Enable/Disable
EOB	End-of-Buffer
EOF	End-of-File
EOL	End-of-Life
EOM	End-of-Mission
EOP	Earth Observatory Program
EOP	End-of-Process
EORT	End-of-Roll Target
EOS	End-of-Scan
EOS	Earth Observation Systems
EOS	Earth Observations Satellite
EOS	End-of-Set
EO&SP	Earth Observatory and Shuttle Programs
EOT	End-of-Tape
EOV	End-of-Volume
EPA	Environmental Protection Agency
EPC	Electrical Power Conditioner
EPI	Euler Parameter Integration
EPS	Electrostatic Plotting Software
ER	Equipment Room
EREP	Earth Resources Equipment Package
EROS	Earth Resources Observation System or Satellite
ERS	Earth Resources Survey
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
ESR	Equipment Service Report
ESTEC	European Space Research and Technology Center
EU	Expander Unit
EVA	Extra-Vehicular Activity
EVAL	Earth Viewing Applications Laboratory
EWO	Engineering Work Order
FAIRS	Full Aperture Infrared Source
F&AO	Financial and Administrative Operations
FAS	Foreign Agricultural Service
FCS	File Control Service
FDD	Fixed (Cartridge) Diablo Disk (Drive)
FDR	Final Design Review
FFP	Federation of Functional Processors
FGS	Fine Guidance System
FHST	Fixed-Head Star Tracker
FID	Final Instrument Definition
FIFO	First-In, First-Out
FIPS	Federal Information Processing Standards
FM	Frequency Modulation
FM	Flight Model
FMEA	Failure Mode and Effects Analysis
FMS	Flight (Segment) Management Subsystem
FO	Flight Operations
FOC	Faint Object Camera
FORTRAN	Formula Translation

FOS	Field Operations Service
FOS	Flight Operations Subsystem
FOS	Faint Object Spectrograph
FOV	Field-of-View
FPA	Focal Plane Assembly
FPG	Final Product Generation
FPP	Floating Point Processor
FPS	Focal Plane Structure
FRD	Facilities Requirement Document
FRS	Film Recorder System
FRUSA/HASP	Flexible Roll-Up Solar Array/Hardened Solar Power System
FS	Flight Segment
ESCM	Federal Supply Code For Manufacturers
FSDF	Flight Segment Development Facility
FSEC	Fairchild Space and Electronics Company
FSK	Frequency Shift Keying
FSS	Flight Scheduling Subsystem
FSS	Flight Segment Simulator
FSS	Flight Support System
FSS	Fine Sun Sensor
FSS S/W	Flight Segment Simulator Software
FT	Fourier Transform
FTS	Federal Telephone System
FW	Fiscal Week
FY	Fiscal Year
FYI	For Your Information
G/C	Geometric Correction
GCD	Geodetic Correction Data or Geometric Correction Data
GCDG	Geodetic Correction Data Generation
GCH	Geometric Correction Matrices
GCM	Geometric Correction Matrix
GCO	Geometric Correction Operator
GCOVS	GCO Verification System
GCP	Geodetic Control Point
GCP	Ground Control Point
GDHS	Ground Data Handling System
GDT	Graphics Display Terminal
GE	General Electric
GE 70	GE Interface Device for DR780
GECP	Geometric Correction Process
GEOREF	Geographic Reference
GES	Ground Electronic Specification
GETSCO	General Electric Technical Service Company
GFE	Government Furnished Equipment
GFIT	Goddard Film Inventory Tape
GFP	Government Furnished Property
GHIT	Goddard HDT Inventory Tape
GHz	Gigahertz (10^9)
GI	General Instruction
GIA	Government Inspection Agency
GM	General Manager
GMF	GCO Microcode File
GMP	Geometric Correction Matrix Calculation Process
GMS	Ground (Segment) Management Subsystem
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GPC	General Purpose Console
GPE	Ground Processing Equipment
GPIP	General Purpose Information Processor
GPS	Global Positioning System
GPT	General Purpose Transformation
GRE	Gamma Ray Explorer
GRFP	Graphite Filled Epoxy
GS	Ground Segment
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSSS	Ground Support System Software
GSTDN	Ground Spaceflight Tracking and Data Network
HAAT	Header, Ancillary, Annotation, Trailer
HATT-L	HATT for Library Maintenance
HAC	HDDR Assignment and Control
HAT	Header Annotation, Trailer
HAL	High-Order Aerospace Language
HCMM	Heat Capacity Mapping Mission
HD	HDT Duplication
HDDR	High Density Digital Recorder
HDDT	High Density Digital Tape
HDE	HDT-R Directory Extractor
HDT	High Density Tape
HDT-A	HDT-Archive Format (Partially corrected radiometrically but not geometrically)
HDT-AM	HDT-A for MSS Sensor Data
HDT-AMC	Copy of HDT-A for MSS Sensor Data
HDT-AT	HDT-A for TM Sensor Data
HDT-ATC	Copy of HDT-A for TM Sensor Data
HDT-I	HDT (Data) Interval
HDT-P	HDT-Product Format (Fully corrected)
HDT-PT	HDT-P for TM Sensor Data
HDT-PTC	Copy of HDT-P for TM Sensor Data
HDTR	High Density Tape Recorder
HDT-R	HDT-Raw Data as recorded in DRRTS
HDT-RM	HDT-R for MSS Sensor Data
HDT-RT	HDT-R for TM Sensor Data
HDT-S	HDT Recorded at White Sands
HDT-SM	HDT-S for MSS Sensor Data
HDT-ST	HDT-S for TM Sensor Data
HgCdTe	Mercury Cadmium Telluride
HIPO	Hierarchy Input Process Output
HRFR	High Resolution Film Recorder
HSCE	High Speed Control Element
HSI	High Speed Interface
HV	Host Vehicle (Landsat-D)
H/W	Hardware
Hz	Hertz (cycles per second)
IAC	Image Analyzer Console
IAP	Integrated Analysis Plan
IAT	Image Analysis Terminal
IAT	Image Annotation Tape
IB	Integration Baseline

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ICCD	Intensified Charge Coupled Device
ICD	Interface Control Document
ICS	Image Correction Support Software
ICS	Interactive Computer Simulator
ID	Identification
IDA	Image Data Acquisition
IDB	Identification Burst
IDBS	International Data Base Systems
IDS	Image Data System
IDT	Investigation Definition Team
IDT	Image Display Terminal
IDT	Industrial Data Terminal Corporation
IDT	Image Data Transmission
I/F	Interface
IF	Intermediate Frequency
IFD	In-Flight Disconnect
IFOV	Instantaneous Field-of-View
IG	Initial Gap
IGF	Image Generation Facility
IIGS	Initial Image Generation Subsystem
IIRV	Improved Inter-Range Vectors
IIS (I^2S)	International Imaging Systems
IM	Information Management
IM	Instrument Module
IMPAC	Image Processing and Analysis Center
IMS	Information Management Subsystem
IMSC	Information Management Subsystem Computer
IMSFCC	Information Management Subsystem FFP Control Computer
IMU	Image Memory Unit
InSb	Indium Antimonide
INTRALAB	Information Transfer Laboratory
I/O	Input/Output
IPC	Initial Product Creation
IPCS	Information Production Control System
IPD	Information Processing Division
IPF	Image Processing Facility
ips	Inches per Second
IPS	Image Processing Subsystem
IPS-1	IPS String No. 1 Computers
IPS-2	IPS String No. 2 Computers
IPSC	IPS Computer
IQL	Interactive Query Language
IR	Infrared
IRB	Integrated Requirements Board
IR&D	Independent Research and Development
IRD	Interface Requirements Document
IRFPA	Infrared Focal Plane Assembly
IRG	Inter-Record Gap
IRIG	Inter-Range Instrumentation Group Time Code
IRIG-A	IRIG Time Code Series A
IRP	Infrared Photometer
IRQ	Interrupt Request
IRU	Inertial Reference Unit
IS	Input Subsystem
ISA	Instrument Standard of America
ISAM	Index Sequential Access Method
ISM	Interface Switching Module
ISS	Image Generation Facility Software Subset
ISU	Input Scanner Unit
IT	Integration Test
I&T	Integration and Test
ITD	Inception-to-Date
ITD	Incurred-to-Date
ITP	Integration Test Plan
IU	Interface Unit
IUE	International Ultraviolet Explorer
IUS	Interim Upper Stage
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
K	A Thousand
K	1024 (Memory Usage Only)
Kb	Kilobit
KB	Kilobyte
Kbps	Kilobits per Second
KBPS	Kilobytes per Second
KCRT	Keyboard Cathode Ray Tube
KL10	CPU for DEC-10 Computer
km	Kilometer
KS	Key Station
KSA	Ku-band Single Access
KSC	Kennedy Space Center
KW	Kilowords
LA36	DEC Hardcopy Terminal
LACIE	Large Area Crop Inventory Equipment
LANDSAT	Land Satellite
LaRC	Langley Research Center
LAS	Landsat-D Assessment System
LAT	Latitude
LBP	Library Build Process
LBR	Laser Beam Recorder
LCP	Left-hand Circularly Polarized
LED	Light-Emitting Diode
LFC	Left-Fill Count
LIDU	Large Image Display Utility
LIFO	Last-In, First-Out
LLA	Adjusted Line Length
LLC	Line Length Code
LM	Library Maintenance
LM	Line Monitor
LMM	Landsat Mission Management
LMSC	Lockheed Missile and Space Corporation
LOE	Level of Effort
LONG	Longitude
LOS	Line of Sight
LOS	Loss of Signal
LPC	Longitudinal Parity Check
LPM	Line Point Marker
LPM	Lines Per Minute
LPM	Load Point Marker
LRA	Laser Retrodirector Array

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LRC	Longitudinal Redundancy Check
LRD	Laser Retrodirector
LSB	Least Significant Bit
LSD	Landsat-D
LS3	Landsat 3
LTC	Light Transfer Characteristics
LTTS	Long-Term Tape Storage Facility
LTU	Line Test Unit
LUN	Logical Unit Number
LV	Launch Vehicle
M	Mega-
M	Million
MA	Multiple Access
MACS	Modular Attitude Control System
MAG	MSS Archival Product Generation
MAP	Macro Array Processor
MASSBUS	High Speed Bus for DEC Equipment
MATSCO	Management and Technical Services Company
Mb	Megabit
MB	Megabyte
MBA	MASSBUS Adaptor
Mbps	Megabits per Second
MCC	Mission Control Center
MCCA	Manual Cloud Cover Assessment Package
MCR	Monitor Console Routine
MCTF	Mission Contractor Test Facility
M&DO	Mission and Data Operations
M&DOD	Mission and Data Operations Directorate
MDM	Multiplex-Demultiplex
MDP	Master Data Processor
MEM	Module Exchange Mechanism
MERITS	Marshall Earth Resources Information Transfer System
METSAT	Meteorological Satellite
MFB	Major Frame Buffer
MFD	Master File Directory
MFS	Major Frame Synchronization
MGSE	Mechanical Government Supplied Equipment
MHS	MSS/HDDR Service
MHW	Multi-Hundred Watt
MHz	Megahertz (10^6)
MIF	Master Information File
MIP	Management Information Process
MIPS	MSS Image Processing System
MIPS	Mega-Instructions per Second
MIS	Mission Interface Subsystem
MIT	Master Information Table
MJF	Major Frame
mm	Millimeter
MM	Minutes
MMF	Mission Management Facility
MMFCC	Mission Management Facility Control Computer
MMF-M	MSS Mission Management Facility
MMF-T	TM Mission Management Facility
MMS	Mission Management System
MMS	Multi-Mission Modular Spacecraft
MMU	Memory Management Unit
MNFS	Minor Frame Synchronization
M&O	Maintenance and Operations
MODEM	Modulator/Demodulator
MOI	Moments of Inertia
MOL	Manned Orbiting Laboratory
MOM	Mission Operations Manager
MOPA	Mega-Operations per Second
MOR	Mission Operations Review
MOU	Memorandum of Understanding
MPP	MSS Preprocessor
MPS	Mission Planning System
MPS	Modular Power Subsystem
MPT	Maximum Power Tracker
MPY	Multiply
MRA	Maintenance Requirements Analysis
MRAM	Maintenance Requirements Analysis Matrix
MRC	Master Reference Cube
MRS	Module Reference System
MS	Mirror Sweep
MSB	Most Significant Bit
MSC	Manned Space Center
MSCD-M	MSS Mirror Scan Correction Data
MSCD-T	TM Mirror Scan Correction Data
MSCO	Mission Support Coordination Office
MSC	Matrix Switch Control
MSEC	Millisecond
MSFC	Marshall Space Flight Center
MSR	Monthly Status Review
MSS	Module Support Structure
MSS	Multispectral Scanner
MSS-A	MSS Archival Data
MSW	Matrix Switch
MT	Magnetic Tape
MTBF	Mean Time Between Failures
MTF	Modulation Transfer Function
MTL	Material
MTM	Mechanical Test Module
MTP	MSS Telemetry Processor
MTTR	Mean Time to Repair
MTU	Magnetic Tape Unit
MUX	Multiplexer
MW	Megawords
N_2	Purified and Filtered Gaseous Nitrogen
N/A	Not Applicable
NAK	Negative Acknowledgement
NAPPS	Nimbus/AEM Preprocessor System
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASTRAN	NASA Structural Analysis (Program)
NASTRAN	NASA Transient Analysis System
NBTR	Narrow Band Tape Recorder
NCC	National Climatic Center
NCC	Network Control Center
NCCS	Network Control Center Subsystem
NCIC	National Cartographic Information Center

ND	Networks Directorate
NDF	Neutral Density Filter
NDPF	NASA Data Processing Facility
NDS	Navigation Data Satellite
NDS	Navigational Development Satellite
NESS	National Environmental Satellite Service
NMI	NASA Management Instructions
NOAA	National Oceanic and Atmospheric Administration
NOCC	Network Operations Control Center
NOSS	National Oceanographic Satellite System
NRC	Nuclear Regulatory Commission
NRZ	Non-Return to Zero
NRZI	Non-Return to Zero Incrementing
NRZ-L	Non-Return to Zero-Level
NSCI	NASA Serial Controller for Input (now SPDI)
NSCO	NASA Serial Controller for Output (now PSDO)
NSSC-1	NASA Standard Spacecraft Computer - Model 1
NSSDC	National Space Science Data Center
NTR	New Technology Representative
NTSC	National Television System Committee
NTTF	Network Test and Training Facility
NTTF	NASA Tracking and Telemetry Facility
OAO	Orbital Astronomy Observatory
OAO	OAO Corporation
OAS	Orbit Adjust Subsystem
OBC	Onboard Computer
OBP	Onboard Processor
OCB	Operational Configuration Baseline
OCC	Operations Control Center
OCD	Operator Control and Display
OCG	Orbit Computations Group
OCR	Optical Character Recognition
ODF	Orbit Determination Facility
ODP	Online Display Process
ODT	Online Debugging Tool
O&M	Operations and Maintenance
OFLS	Offline System
ONLS	Online System
OPS	Operations
O/S	Operations Supervisor
OS	Operating System
OSCD	Orbital Support Computing Division
OSO	Orbiting Solar Observatory
OSR	Optical Solar Reflector
OSS	Office of Space Science
OSS	Operating System Software
OTA	Optical Telescope Assembly
OTDA	Office of Tracking and Data Acquisition
PA	Public Address
PAO	Public Affairs Office
PAM	Pulse Amplitude Modulation
PATH	Orbital Path
P/B	Playback
PBX	Private Branch Exchange
PC	Production Control

PC	Program Counter
PC	Printed Circuit
PCB	Printed Circuit Board
PCD	Payload Correction Data
PCD	Photon Counting Detector
PCD-M	MSS Payload Correction Data
PCD-T	TM Payload Correction Data
PCE	Pipeline Control Executive
PCM	Pulse Code Modulated
PCP	Product Control Procure
PCP	Program Control Procedure
PCS	Payload Correction Subsystem
PCU	Power Control Unit
PD	Payload Disconnect
PD	Programmable Decommutator
PDF	Programmable Data Formatter
PDL	Program Design Language
PDP	Programmable Digital Processor
PDP	Peripheral Data Product
PDR	Preliminary Design Review
PDR	Problem/Defect Report
PDSS	Precision Digital Sun Sensor
PDU	Power Distribution Unit
PE	Performance Evaluation
PE	Phase Encoded
P&E	Plant and Equipment
PES	Performance Evaluation Subsystem
PET	Predicted Ephemeris Tape
P/F	Protoflight
PFD	Pre-Flight Disconnect
PF&F	Protoflight and Flight
PFI	Program Funding Instructions
PGCOP	Product Generation CCT Output Process
PGHIP	Product Generation HDT Input Process
PGHSM	Product Generation HDT-P Simulator
PGLOP	Product Generation LBR Output Process
PGLSM	Product Generation LBR Simulator
PGM	Program Manager
PGMON	Product Generation Pipeline Monitor Process
PGP	Product Generation Process
PGS	Product Generation Subsystem
P/I	Policy/Instruction
PI	Principal Investigator
PIF	Pseudo Image File
PIGP	Pseudo Image Generation Program
PIL	Pixel Interleaved by Line
PIO	Programmed Input Output
PIP	Peripheral Interchange Program
PIR	Program Information Request/Release
PIXEL	Picture Element
PKG	Package Design Specification
P/L	Payload
PLACE	Post Landsat-D Advanced Concepts Evaluation
PM	Preventive Maintenance
PM	Propulsion Module
PMB	Program Management Budget
PMD	Post-Mortem Dump

PM/FL	Performance Monitor/Fault Location
PMM	Program Maintenance Manual
PMP	Premodulation Processor
PMT	Photomultiplier Tube
PN	Pseudo Noise
PO	Project Office
PO	Purchase Order
POCC	Payload Operations Control Center
POD	Project Operations Directors
POP	Project Operating Plan
PORTS	Preliminary Operations Requirements and Testing Support
POWO	Purchase Order Work Order
PPL	Photo Processing Lab
PPL	Preferred Parts List
PPO	Program Participation/Opportunities System
PPS	Photographic Processing Subsystem
PRMIS	Printing Resource Management Information
PRN	Pseudo Random Noise
PRO	Payload Receiving Operations
PROM	Programmable Read-Only Memory
PRP	Performance Recognition Program
PRU	Power Regulator Unit
PS	Polar Stereographic
PSDO	Parallel-to-Serial Data Output Device
PSF	Photo/Shipping Support Facility
PSK	Phase Shift Keying
PSM	Programmable Sync Module
PSR	Project Status Review
PSU	Power Supply Unit
PSU	Power Switching Unit
PVS	Pressure Vessel Spacecraft
PWB	Printed Wiring Board
PWM	Pulse Width Modulated
Q&A	Qualification and Acceptance
QA	Quality Assurance/Assessment
QAF	Quality Assessment Film
QAP	Quality Assessment Process
QAP	Quality Assurance Procedure
QAP	Qualification and Acceptance Program
QC	Quality Control
QFP	Quality Assurance Film Generation Process
QIO	Queued Request for Input/Output
QIO	Queue Input/Output Process
QLD	Quick Look Display
QLM	Quick-Look Monitor Unit
QLP	Quick-Look Processor
QLPS	Quick-Look Processing System
QPSK	Quadrative Phase Shift Keyed
QRWO	Quick-Reaction Work Order
QSL	Quarter Scan Line
RAA	Reformating Ancillary Annotation
RAM	Random Access Memory
RBV	Return Beam Vidicon
RC	Radiometric Correction
RCFP	Radiometric Correction Function Calculation Process
RCHP	Right-Hand Circularly Polarized
RCP	Registration or Relative Control Point
RCP	Right-Hand Circularly Polarized
RCV	Receive
R&D	Research and Development
RDCP	Radiometric Corrected Process
RDCP	Radiometric Function Calculation Process
RDT	Raw Data Tape
REC	Record
REM	Rocket Engine Module
RF	Radio Frequency
RFC	Right-Fill Count
RFH	Request for Hire
RFOV	Resolution Field-of-View
RFP	Request for Proposal
RH780	Massbus Adaptor for DEC VAX-11/780
RID	Review Item Discrepancy
RIU	Remote Interface Unit
RLUT	Radiometric Lookup Table
RMS	Remote Manipulator System
RMS	Root Mean Square
RMS	Record Management Services
ROM	Read-Only Memory
ROW	Geographic Frame Reference
RP06	DEC 176 MB Disk or Removable Disk Storage Unit
RP07	DEC 283 MB Disk
R/PA	Receiver/Processor Assembly (GPS)
R&PA	Reliability and Product Assurance
RPM	Revolutions Per Minute
RPP	RBV Preprocessor
R&QA	Reliability and Quality Assurance
RSE	Receiving Site Equipment
RSE	Remote Site Equipment
RSX-11M	Multi-Tasking Operating System Software
R/T	Real-Time
RTG	Radiosotope Thermoelectric Generator
RTTS	Real-Time Test System
RX	Receive
SA	Single Access
SA	Solar Array
SAD	Solar Array Drive
SADAPTA	Solar Array Drive and Power Transfer Assembly
SAIL	Space Applications and Information Library
SARJA	Solar Array Retention, Deployment and Jettison Assembly
SB	Stage Baseline
SBC	Single Board Computer
SBI	Synchronous Backplane Interconnect
SBRC	Santa Barbara Research Center
SBS	Space Background Simulator
SBU	Strategic Business Unit
S/C	Spacecraft
SC	Signal Conditioning
SCA	Signal Conditional Assembly
SCAMA	Switching, Conferencing and Monitoring Arrangement

SCCB	Software Change Control Board
SCD	Systematic Correction Data
SCHS	Spacecraft Hardware Simulator (MSS Simulator)
SCI	Serial Control Interface
SCII	Serial Control Interface for Input (now SPDI)
SCIO	Serial Control Interface for Output (now PSDO)
SCL	Subcontract Labor
SCM	Systematic Correction Matrix
SCP	Sun Calibration Process
SCR	Scaler Control Register
SCR	Software Change Request
SC&SU	Signal Conditioning and Switching Unit (SU)
SCT	System Control Terminal
SD	Space Division
SDF	Software Development Facility
SDHS	Satellite Data Handling System
SDISS	Satellite Data Ingest and Storage Subsystem
SDSB	Satellite Data Services Branch
SEAM	Software Engineering and Management Program
Sec	Seconds of Arc
SECO	Secondary Electron Conduction Orthicon
SEOPS	Standard Earth Observation Package Satellite
SEOS	Synchronous Earth Observation Satellite
SI	Science Instruments
SIAT	Special Image Annotation Tape
SICM	Science Instrument Central Module
SIDU	Small Image Display Utility
SIF	Simulation Image File
SIM	Simulator
SIP	System Image Preservation
SIRD	Support Instrumentation Requirement Document
SIU	Sectorizer Ingest Unit
SLAT	Spacecraft Location and Attitude Tape
SLC	Scan Line Corrector
SLER	Synch Loss Error Rate
SLP	Source Language Input Program
SLS	Scan Line Sync
SLS	Start-of-Line Sync
SMA	S-Band Multiple Access
SMA	Scan Mirror Assembly
SMM	Solar Maximum Mission
SM&O	Support Maintenance and Operations
SMP	Scan Monitor Pulse
SMR	Software Modification Record
SMSA	Standard Metropolitan Statistical Area
S/N	Signal-to-Noise Ratio
SNR	Signal-to-Noise Ratio
SOM	Space Oblique Mercator
SOP	Standard Operating Procedure
SOW	Statement of Work
SP	Stack Pointer
SPC	Small Peripheral Controller
SPD	DEC Software Product Description
SPDI	Serial-to-Parallel Data Input Device
SPM	Sub-Project Manager
SPP	Special Purpose Processor
SPR	Software Problem Report

SPRD	Site Preparation Requirements Document
SPS	Segment Processing Subsystem
SPU	Scene Processing Unit
SQA	Software Quality Assurance
SRCDR	Software Requirements and Conceptual Design Review
SRCDS	Software Requirements and Conceptual Design Specification
SRR	System Requirements Review
SRS	Software Requirements Specification
SRS	System Requirement Specification
SRT	Supporting Research and Technology
SS	Seconds
S/S	Subsystem
SSA	S-Band Single Access
SSC	Science Support Center
SSDA	Sequential Similarity Detection Algorithm
SSM	Support Systems Module
SSO	Space System Operations
SSRR	Systems Software Requirements Review
SST	Synchronous System Trap
ST	Space Telescope
STACC	Standard Telemetry and Command Components
STACC-CU	STACC Central Unit
STACC-STINT	STACC Interface Unit
STC	System Test Console
STD	System Test Director
STD	Standard
STOL	System Test and Operation Language
STDN	Spaceflight Tracking and Data Network
STEP	Space Technology Engineering Program
STINT	Standard Interface for Onboard Computer
STINT	STACC Interface Unit
STOCC	Space Telescope Operations Control Center
STOL	System Test and Operations Language
STP	System Test Plan
STR	Standard S/C Telemetry Recorder
STR	Standard Tape Recorder
STR	System Test Review
STS	Space Transportation System
STS	Shuttle Transportation System
STSOC	Space Telescope Scientific Operations Center
SU	Switching Unit
SVS	Space Vehicle Specification
S/W	Software
SWG	Science Working Group
SYCI	System Corrected Images
TA	Transistor Adaptor
TAC	Telemetry and Command
TAC	TM Adaptive Capability
TAS	TM Archival Product Generation
TAM	Three Axis Magnetometer
TAS	Tape Archive and Storage
TBA	To Be Announced
TBD	To Be Determined
TBD	To Be Defined
TBR	To Be Resolved

TBS	To Be Supplied
TBV	To Be Verified
T/C	Time Code
TCC	Time Code Controller
TCG	Time Code Generator
TCI/OSC	Time Code In/Oscillator
TCOM	Army Test and Evaluation Command
TCO/PAN	Time Code Out/Panel
TCS	Thermal Control System
TCU	Time Code Unit
T&D	Test and Diagnostic
TD	Test Directives
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
T&E	Test and Evaluation
TEP	Telemetry Extraction Process
TGS	Transportable Ground Station
TIPS	TM Image Processing System
TIROS-N	Television Infrared Observing System
TIS	Technical Information Series
TLM	Telemetry
TM	Thematic Mapper
TM	Telemetry
TMV	Telemetry Volts
TOD	True-of-Date
TP	Telemetry Processor
TPG	Test Pattern Generator
TPL	Test Plan
TR	Tape Recorder
TRB	Test Review Board
TRF	Tracking and Receiving Facility
TRK	Track (HDDR)
TRKG	Tracking
TRP	Technical Recognition Program
TRW	TRW Defense and Space Systems Group
T/S	Thermal/Structural
TSIM	Test and Simulation Subsystem
TSSC	Technical Support Services Company
TSSF	Tape Staging and Storage Facility
TTA	Triangular Transition Adaptor
TT&C	Telemetry Tracking and Command
TTL	Transistor Logic Device
TTY	Teletype Operator Console
TU45	1600 bpi Magnetic Tape Unit
TU72	6250 bpi Magnetic Tape Unit
TU78	6250 bpi Magnetic Tape Unit
TV	Television
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier
TX	Transmit
UARS	Upper Atmosphere Research Satellite
UBA	Unibus Adaptor
UBC	Unit Block Controller
UDDPM	Unload DDP Module
UDF	Unit Development Folder
UFD	User File Directory
UHF	Ultra High Frequency
UIC	User Identification Code
U/L	Uplink
UNIBUS	Universal Bus
UQPSK	Unbalanced Quadrature
USART	Universal Synchronous Asynchronous Receiver Transmitter
USB	Upper Side-Band
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VA	Value Analysis
VAC	Volts, Alternating Current
VAP	Verification Acceptance Program
VAX-11/780	Virtual Address Extension DEC Model Computer 11/780
VCO	Voltage-Controlled Oscillator
VCRI	Verification Cross-Reference Index
VDC	Volts, Direct Current
VE	Value Engineering
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VICAR	Video Image Communication and Retrieval
VIP	Virtually Interfaced Peripheral
VM	Value Management
VMS	Virtual Memory (Operating) System
VPASS	Video Processor and Sync Seperator
VPIR	Video Processor/Image Recorder
V/T	Vacuum Thermal
VT	Verification Test
VT78	Intelligent CRT Terminal
VT100	Non-Intelligent CRT Terminal
VTR	Video Tape Recorder
W/B	Wideband
WBM	Wideband Module
WBS	Work Breakdown Structure
WBSS	Wideband Subsystem
WBVT	Wide Band Video Tape
WBVTR	Wide Band Video Tape Recorder
WCS	Writeable Control Store
WFC	Wide-Field Camera
WO	Work Order
WPC	Word Processor Center
WPM	Work Package Manager
WRS	World Reference System
WSMR	White Sands Missile Range
WTR	Western Test Range
XMIT	Transmit
XMTR	Transmitter
Z	Zulu Time (GMT)
ZTS	Zoom Transfer Scoop
ZWC	Zero Word Count
μ	Micro-
μm	Micrometer (-10^{-6} Meter)
μp	Microprocessor
μS	Microsecond

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LAS Software Functions (Partial Listing)

BAYES	Max. Likelihood Classification
BINARY	7 Functions: +, -, *, /, and, or, XOR
CALAMP	Analyze CAL Lamp Data
CANAL	Canonical Analysis
CHAROUT	Writes Annotation to Bit Plane
CLASSMAP	Generate Class Map Film Product
CLUSTER	Clustering
COLGEN	Generate Pseudo Color Table
COLSLIC	Movable Zero Band in Color LUT
COMBCLS	Combine Class
CONCAT	Concatenate Images
CONTOUR	Contour Image
CONVOLVE	Convolve Image (Smoothing)
COPY	Copy or Subset Image
COVAR	Covariance Matrix
CURSTRK	Figure Drawing with a Cursor (Graphics Proc.)
DESPIKE	Remove Spikes
DISCRIM	Discriment Analysis
DROPCLS	Delete Class
DROPSITE	Delete Training Site
EDGE	Extract Edges in Image
EDGECORR	Register Images by Edge Correlation
EDITSITE	Edit Training Site Coordinates
FFT1	1-Dimensional Fourier Transform
FFT1FL	1-Dimensional Fourier Transform Filter
FFT2	2-Dimensional Fourier Transform
FFT2FL	2-Dimensional Fourier Transform Filter
FIGLPEN	Figure Drawing with a Light Pen (Graphics Proc.)
FILM	Generate Film Product
FIT	Scale Image by Histogram
FLICKER	Blink Mode Display
FROMTV	Quick Copy of IAT to Disk
FT2PIX	Generate 2-Dimensional Fourier Display
FT1PIX	Generate 1-Dimensional Fourier Display
GCDG	Generate Geometric Correction Data
GEOM	Perform Geometric Transformation (Rubber Sheet) for LAS
GRAPHICS	Graphic Functions Via Console Button
GREYREG	Register Images by Grey Level Correlation
GRSLIC	Movable Zero Band in LUT
HINDU	Histogram Inspired Cluster
HISTEQ	Histogram Equalization RLUT Generation
JITTER	Analyze Jitter Effects
KARLOV	Karhunen-Loeve Transform
LINEOFF	Line Offset Correction

LINEREPR	Repair Bad Lines
LIST	List and Histogram Image Window
LISTSTAT	List Stats File
LUTEDT	Edits LUT File
LUTLOD	Load Specified LUT from LUT Disk File
LUTSAV	Save LUT on Disk File
MASKSTAT	Statistics of Mask Image
MEDFIL	Perform Median Filtering
MINDIST	Minimum Distance Classification
MOSAIC	Mosaic Images
MSSA2P	Resample MSS A-Image to P-Image
PARALL	Parallelpiped Classification
PFILM	Generate P-Type Film Product
POLYSITE	Polygonal Site Selections
PSEUDO	Load Pseudo Color Tables (LUTLOD Proc.)
RADIOM	Apply RLUT to Image
RECORD	Copies TV to TV (Thru LUT Optional)
RENCLS	Rename Class
RLUT	TM A-Priori RLUT Generation
SAVIAT	Saves IAT B/W Configuration
SCALE	Convert Halfword Image to BYTE Image
SCANNER	Read Scanner/Digitizer
SCDFT	Perform Fourier Analysis of SCD HFM
SC[illegible]	Scroll Disk Image to IAT's
SEGM[illegible]	Segment Offset Correction
SEGMREPR	Repair Image Blemish
SETTV	Redefines IAT B/W Configuration
SHADE	Shade Plot of Image Window
SITES	Rectangular Site Selections
SPLIT	Split Screen Operation
STATS	Generate Stats File (Training Site)
STRETCH	Stretch Image Contrast
TESTGEN	Generate Test Images
TIEPTS	Generate Control Grid for Resampling
TMA2P	Resample TM A-Image to P-Image
TMHIST	Histograms of TM Image for RLUT
TOTV	Quick Copy of 'TV-Size' Image to IAT
TRANSDIV	Transform Divergence
UMAP	Uniformity Mapping
UNARY	5 Functions: +, *, NOT, EXP, LOG
VEGGIN	Vegetative Index
WTGEN	Weight Generator for FFT2FL
XFERSITE	Transfer Training Site
ZOOM	Enlarge or Reduce Image

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